

PROBLEMS OF FISH CULTURE ECONOMICS
with special reference to
CARP CULTURE IN EASTERN EUROPE



EUROPEAN INLAND FISHERIES ADVISORY COMMISSION
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

EUROPEAN INLAND FISHERIES ADVISORY COMMISSION (EIFAC)

EIFAC documents are issued in three series:

EIFAC Reports

Report of each Session in English and French

EIFAC Technical Papers

Selected scientific and technical papers, including some of those contributed as working documents to Sessions of the Commission or its Sub-Commissions. Published in English and French, or one of these languages.

EIFAC Occasional Papers

Papers of general interest to the Commission. Published in the language submitted, either in English or French; sometimes in both languages.

Copies of these documents, when still available, can be obtained from:

Secretary
European Inland Fisheries Advisory Commission
Fisheries Department
FAO
Via delle Terme di Caracalla
00100 Rome, Italy

EIFAC Technical Paper

PROBLEMS OF FISH CULTURE ECONOMICS WITH SPECIAL REFERENCE
TO CARP CULTURE IN EASTERN EUROPE

by

Marian Leopold
Inland Fisheries Institute
blok 5, 10-957 Olsztyn
Poland

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1981

This One



NFK4-X40-HJKJ

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries

M-44

ISBN 92-5-101152-4

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying or otherwise, without the prior permission of the copyright owner. Applications for such permission, with a statement of the purpose and extent of the reproduction, should be addressed to the Director, Publications Division, Food and Agriculture Organization of the United Nations, Via della Terme di Caracalla, 00100 Rome, Italy.

© FAO 1982

PREPARATION OF THIS DOCUMENT

This paper was prepared by the Convener of the EIFAC Working Party on the Economic and Technical Appraisal of Different Types of Fish Culture, Dr M. Leopold (Poland), on the basis of data collected and summarized by the Working Party. The assistance of the following experts who were kind enough to review the manuscript is hereby acknowledged: Dr M. Lukowicz, Dr U. Schmidt, Dr Y.C. Shang, Dr J. Vacek, Mr A.R. Gloyne and Dr C.J. Shepherd. The author is particularly grateful to Dr John A. Bardach and Dr H. Webber from the USA for their valuable assistance as well as to Dr Maria Bninska, without whose help this work would not have been done.

Distribution:

Author

Members of the EIFAC Working Party on the
Economic and Technical Appraisal of
Different Types of Fish Culture
EIFAC Mailing List
FAO Fisheries Department
FAO Regional Fishery Officers

For bibliographic purposes this document should
be cited as follows:

Leopold, M., Problems of fish culture economics
1981 with special reference to carp
culture in eastern Europe. EIFAC
Tech.Pap., (40):99 p.

ABSTRACT

This document deals with the problems of fish culture, particularly carp, in eastern Europe. It reviews the types, methodology and role of fish culture and the economic analysis of this activity. It shows that there is no universal method for economic analysis of fish culture, especially if it has to be used for comparing economic efficiency of fish farming activities, and presents a general simplified outline of feasible economic analysis.

CONTENTS

	Page
OBJECTIVES	1
PART I - TYPES, METHODOLOGY AND ROLE OF FISH CULTURE	2
1. INTRODUCTION	2
1.1 Characteristics of Fish Culture	2
1.2 Non-measurable and Non-fishery Elements of Fish Culture	4
1.3 Main Types and Methods of Fish Culture	10
2. SIMPLIFIED MODEL OF FISH CULTURE PRODUCTION AND ECONOMIC	14
2.1 Set of Natural Factors	14
2.2 Set of Economic Factors	16
2.3 Set of Production Factors	17
2.4 Set of Non-measurable and Non-fishery Factors	18
3. GENERAL REMARKS ON METHODOLOGY	21
4. GENERAL ROLE OF FISH CULTURE	24
4.1 Comparison of the efficiency of fish culture with other forms of animal production	25
4.1.1 Efficiency of fish culture expressed in natural indices	25
4.1.2 Efficiency of fish culture expressed in economic indices	28
5. SPECIFIC ROLE OF FISH CULTURE	31
5.1 Specific Role of Fish Culture as a Producer of Animal Protein, Source of Income, Employment, and Activity on a Local Scale	31
5.2 Role of Fish Culture in Changing Negative Goods into Positive Goods, and Especially in Maintaining the Quality of Waters	33
5.3 Utilization of Waste Lands and Barren Waters by Fish Culture	33
5.4 Other Specific Roles of Fish Culture	34
6. INTENSITY OF FISH CULTURE AND ITS MEASURES	35
PART II - ECONOMIC ANALYSIS OF FISH CULTURE	41
1. FACTORS AFFECTING THE ECONOMICS OF FISH CULTURE	41
1.1 Size of Ponds, Pond Complexes, Pond Farms, and Other Units of Fish Culture	41
1.1.1 Size of ponds	41
1.1.2 Size of pond complexes	42
1.1.3 Size of fish farms	50
1.2 Depth of Ponds	55
1.3 Selected Examples of the Economic of Means, Measures, and Methods of Fish Culture	57
1.3.1 The effect of feeding on the economics of fish culture	57
1.3.2 The effect of fertilization on the economics of fish culture	64
1.3.3 The effect of other biotechniques on the economics of fish culture	67
1.3.4 The effect of stocking rate on the economics of fish culture	70

	<u>Page</u>
1.3.5 The effect of the size of stocking material and rearing systems on the economics of fish culture	73
1.3.6 The effect of polyculture on the economics of fish culture	75
1.3.7 The effect of the period of pond filling on the economics of fish culture	77
1.3.8 The effect of selection on the economics of fish culture	78
1.3.9 The effect of measure against fish diseases on the economics of fish culture	78
1.3.10 The effect of mechanization on the economics of fish culture	79
1.3.11 The effect of maintenance and improvement of ponds on the economics of fish culture	80
1.3.12 The effect of expenditures on the economics of fish culture	82
2. GENERAL OUTLINE OF FEASIBLE ECONOMIC ANALYSIS OF FISH CULTURE CONCLUDING REMARKS	85
PART III - REFERENCES	88
A. PUBLISHED PAPERS	88
B. UNPUBLISHED PAPERS	99

OBJECTIVES

The main objectives of this paper can be stated as follows:

- demonstrate the various factors which need to be taken into account in the economic appraisal of fish culture;
- demonstrate the difficulties involved in any attempts at reliable assessments of fish culture activities;
- demonstrate that detailed economic assessment of fish culture has to take into account the many interrelated and interacting variables in fish culture systems;
- indicate those measures of economic efficiency which are best suited to the analysis of fish culture;
- present an analytical framework of fish culture activities as a suitable basis for decision-making and policy planning;
- present comprehensive information on the different forms of fish culture, including technical and economic aspects and their means of improvement.

This paper covers the various levels of decision-making involved in planning for fish culture, as well as technically oriented economic data connected directly with farming measures and practices. Hence, the document is divided into two parts. Part I deals mainly with broad economic, political and ecological planning variables, and thus is addressed primarily to the decision-makers beyond the farm or regional farm level, and, to some extent, to scientists working in the field of fish culture. Part II is more farm-related and technical, being directed primarily to fish farmers and fish-farm managers.

The document is based on the materials collected by the Working Party and on the literature data. In reviewing the literature, special attention was given to an impressive number of papers of East European origin, which so far are not known outside the region. Consequently, this paper deals most of all with the economics of carp pond fish culture. It should, however, be remembered that carp production represents the highest mass of total fish production from fish culture, not only in Eastern Europe but also in almost all countries represented in the Working Party. Under Eastern European climatic conditions, carp constitutes the main source of protein compared to other fish species; its production does not necessitate greater expenses, and its farming in ponds will for long remain the most common form of aquaculture.

PART I - TYPES, METHODOLOGY AND ROLE OF FISH CULTURE

1. INTRODUCTION

1.1 Characteristics of Fish Culture

Fish culture occupies a special position among the different branches of livestock production and related economic activities. It is difficult to define this position due to the numerous types of methods of fish culture, different intensification measures, and the complex multiple value of this type of activity. Furthermore, the problem becomes even more difficult by the fact that fish culture needs to satisfy the highly differentiated demands of modern man.

The necessity of defining the position of fish culture is determined by the growing need for its economic assessment and comparing its effectiveness with other fields of material production. In many cases this need is not connected with the production as such; for instance, it may be necessary to analyse the effectiveness of utilizing a given water body for fish culture versus its utilization for recreation, sewage collection, etc.

The characteristics of fish culture consist essentially of the multiplicity of its forms from simple harvesting to modern, highly developed industrial production. At the very beginning of this succession, the "cultured" fish stock and the production environment are manipulated exclusively through the fishery exploitation, the rest being done by nature itself. Whereas at the end of this succession there are even electronically regulated and controlled systems affecting almost all environmental parameters, fish stock and biotechniques, in between these two extremes there is almost an infinity of various forms of fish culture.

The essence of each form of fish culture consists of generally understood influences upon the production environment and the object of production. The varying extent of this influence defines the position of the given form of fish culture with respect to other branches of material production; with particular respect to the production of other food products. The most primitive (although not necessarily the least economically efficient) forms of inland fisheries closely resemble sea fisheries. In both cases management methods are either of the same type, or very similar to each other. Nevertheless, this does not imply that more advanced forms of fish culture do not have any common points with fisheries. The basic common points are: the same object of production interest (fish) and the production environment (water). Hence independently of the form of management, many similarities are to be found. Thus, fish must always fulfill certain conditions of food products/storage of the fish, its handling and processing, etc. Furthermore, production is based on the natural environment, and it is necessary to take into account generally understood environmental effects on production and to adopt a specific bioeconomic approach.

The more advanced and most common forms of fish culture are those in which production still significantly depends upon the natural environment, but some of its parameters may be regulated, controlled, and improved by various measures. The same applies to the cultured fish species and the biotechniques of rearing. Except for the most modern methods of fish culture, it is this situation which currently predominates in world fish culture, making it most similar to agricultural production.

This similarity places fish culture somewhere in between plant and animal production, with methods typifying both these branches of agriculture, applied simultaneously, although with different intensity, depending on the level of fish culture. Usually, in fish culture of lower intensity those methods characteristic of plant production prevail, while higher intensity is mostly connected with methods of animal production. This point can be best exemplified by warm-water fish culture, for instance, carp culture in ponds. In this case such measures as fertilization and cultivation of the pond bottom belong to methods of plant production, whereas feeding and veterinary services - to methods typical of animal production. With increased production, the role of the latter measures increases, and of the former decreases. In extreme cases, such as tank culture, the role of the methods typical for

plant production is practically negligible. This is well illustrated by economic calculations, particularly by the structure of production costs. Details of this point will be discussed elsewhere.

The most modern forms of fish culture, in which dependence of fish production on the natural environment is significantly reduced, are those resembling commercial fattening of warm-blooded animals of an industrial nature and the structure of the costs of production reflects this state.

The diverse forms of fish culture, which constitute its characteristic feature, are closely connected to, and result from, another typical feature of fish culture, diversity of applied methods and means of intensification. This variety, in turn, results from the different possibilities for intensifying various forms of fish culture, as determined by natural, historic and economic conditions. All these factors interact with each other, constituting a complicated chain, or network of cause and effect, which have shaped and/or are shaping the form of fish culture. The manner of intensification of fish culture will be totally different under different climatic conditions; thus, in the case of farming based on old ponds, in some cases constructed as far back as the Middle Ages, and in modern farms constructed recently, they will differ as regards constraints on resources of manpower, and on resources of food, energy, capital, land, water, etc.

Further implications result from the fact that fish culture utilizes different types of waters (stagnant, flowing, fresh, brackish, salt, clean, polluted, heated, etc.), different water bodies (lakes, ponds, dam reservoirs, rivers, tanks, cages, enclosures, etc.), and different fish species (warm- and cold-water, predatory, non-predatory, etc.). The problem is still more complicated by the variety of aims of the fish culture, its different significance depending on the situation, etc.

The above-mentioned characteristics of fish culture point to the enormous difficulties in an unequivocal assessment of its economic efficiency under comparable conditions or situations. The problem is made even more difficult by the fact that there exists virtually no uniform system of bookkeeping, as exemplified by the sometimes insuperable difficulties encountered in completing, and especially in interpreting, the EIFAC/FAO pro-formae on economic and technical appraisal of different forms of fish culture, or by the proposition of introducing universal bookkeeping methods (Berge, 1976; Gerhardson, 1975) or by the suggestions that all studies should be based on agricultural bookkeeping. It can be stated that the lack of any satisfactory methods of economic appraisal, resulting from the lack of uniform accounting, also constitutes a specific feature of fish culture. Establishing the rules of such appraisal is difficult. Apart from the reasons discussed above, this difficulty results also from the following specific features of fish culture:

its role over and above the value of fish produced, i.e., the non-fishery value of fish culture,

possibilities of utilizing for fish culture such water bodies which are primarily used for other purposes,

different purposes of fish culture.

These features dictate that the economic efficiency of fish culture should be assessed and analysed much more broadly than in the case of "classical" economic accounting used in agriculture.

All the specific features of fish culture should be taken into account in each form of its economic appraisal. An interesting, if imperfect, attempt at such a multilateral approach to the problem of economic appraisal of fish culture is brought out in the case studies prepared by the EIFAC WP (Case study No. 4, 1974; Case study No. 5, 1974; Case study No. 6, 1975). These case studies point to a close connexion between the economics of fish culture and its non-fishery and non-measurable value, as well as the need to consider them, both in economic appraisal and in practical managements and economic activity.

References

See references numbered 15, 190, 194, 195, 196.

1.2 Non-measurable and Non-fishery Elements of Fish Culture

Water resources suitable for human use are becoming less and less abundant. This decrease is both relative (resulting from increasing population) and absolute (resulting from the degradation of water resources, mainly through pollution. The phenomenon applies especially to freshwater resources, i.e., those of interest to this study. In economic terms, water resources can no longer be treated as free goods, they have already become economic goods, and goods that become exhausted; their preservation necessitating increased economic expenditure. This shows the necessity of undertaking economic appraisal on a broader scale than has been done so far. Modern man has much deeper, although still imperfect, understanding of the multiple value of water resources and of the natural environment which creates these resources. Nevertheless, first attempts at applying economic calculations have shown that several values of the environment are either difficult to evaluate, or can be only roughly assessed, or alternatively cannot be measured as yet due to the lack of proper quantification methods.

Fish culture, as one of the forms of utilizing water resources and in some cases creating them, cannot avoid these difficulties. Each appraisal of its economic efficiency is accompanied by various non-fishery (and as a rule non-measurable) elements which should be taken into account. This is quite irrevocable in view of the fact that the exhaustion of water resources is accompanied by a growing need for the development of fish culture. Proper allocation of inputs (means and measures) for different forms of fish culture under the given conditions (such as would maximize economic efficiency of fish culture and at the same time optimize the non-fishery elements) constitutes an extremely significant problem in the decision-making process, especially in the context of other forms of animal production. The need for optimization of these elements should be stressed as antagonistic or non-antagonistic values of fish culture in relation to other values of water resources are defined by these elements. This problem becomes especially important in view of the economic appraisal of the efficiency of fish culture on a micro- and macro-scale.

It should be pointed out that fish culture always possesses some non-fishery values and that these values can be both positive and negative. Hence, each assessment of the economic effectiveness of fish culture (E) should consist of two elements:

1. economic appraisal referring to the value of fish culture as such: "V",
2. economic appraisal referring to non-fishery values of fish culture:
" $K = K_v + K_k$ ", where K_v = measurable non-fishery values, K_k = non-measurable non-fishery values.

Hence, in practice, full economic appraisal of fish culture can take the following forms:

1. $E = V + K_k + K_v$
2. $E = V - K_k + K_v$
3. $E = V + K_k$
4. $E = V - K_k$
5. $E = V + K_k - K_v$
6. $E = V - K_k - K_v$

Even the most superficial analysis of these variants leads to conclusions which are significant for decision-making.

To simplify, it can be assumed that the values of particular parameters in the above equations are the same, i.e., that all "V" values are equal to each other, so are all " K_v " values, all " $-K_k$ " values, etc. As is seen in the case of narrowly defined economic appraisal, such as takes into account only "costs and results" of fish culture, all the above variants (1-6) are of the same economic effectiveness since we have assumed that all "V" values are equal to each other.

On the other hand, if we look upon the relation "costs-results" more broadly, introducing also into our analysis measurable non-fishery elements (K_v), the six variants will differentiate into three groups of different economic effectiveness:

- most effective (variants 1 and 2)
- effective (variants 3 and 4)
- least effective (variants 5 and 6)

Further introduction of non-measurable, non-fishery values (K_k), i.e., practical extension of the analysis beyond the classical relation "costs-results" and making it closer to "cost-benefit" analysis, will differentiate the six variants as follows:

- | | |
|---|-----------|
| totally effective (beneficial) | (1) |
| effective (beneficial) | (3) |
| not defined as regards effectiveness (benefits) | (2 and 5) |
| ineffective (not beneficial) | (4) |
| totally ineffective | (6) |

Although obvious economic and other conclusions resulting from this analysis do not solve the complex and difficult problems of economic appraisal of different forms of fish culture, they may be very helpful in practice in undertaking proper decisions, optimal from several points of view.

Quantification of non-fishery values of fish culture (K) becomes the most difficult problem, and especially any sensible evaluation of non-measurable values (K_k). The matter is of primary importance as in many cases the decision-maker faces an alternative, and is forced to select from a number of K_k values those that may serve as the criteria for undertaking the decision.

The significance of non-measurable values is determined by the particular conditions of fish culture. Since these values are non-measurable as yet, their selection will always be more arbitrary than objective. Nevertheless, it should always be based on the analysis of these conditions, made as comprehensively and as objectively as possible. If, for instance, we have two types of fish culture (S_1 and S_2) of the same measurable values:

$$V_1 \pm K_{v1} = V_2 \pm K_{v2}$$

and with K_{k1} and K_{k2} representing specific beneficial environmental values (physiotactic effect), then the evaluation of this element in conditions of the advanced environmental degradation (for example in S_1) will be higher than in the case of a less degraded environment (S_2):

$$K_{k1} > K_{k2}$$

Hence:

$$V_1 \pm K_{v1} \pm K_{k1} > V_2 \pm K_{v2} \pm K_{k2}$$

and thus:

$$E_1 > E_2$$

It can be concluded that economic appraisal of different forms of fish culture must be differentiated, being adapted to and depending also upon non-measurable values of fish culture. The same conclusion results from the analysis of numerous types of fish culture, in which its particular forms are characterized by a number of non-measurable elements. In this context attention is drawn to Case Study No. 5, prepared by Winiarczyk (Poland) for the EIFAC Working Party. The author has made a most promising attempt at using a point (score) scale for the evaluation of non-measurable values of fish culture.

Non-fishery values of fish culture (or the non-measurable ones) can be classified into some basic groups. Apart from the values connected with fish production as such, we can distinguish other values of fish culture as follows:

- A. the element of complex water management,
- B. the element of local management of water resources,
- C. the element of protection, preservation, and shaping of the natural environment,
- D. the element of various non-production benefits,
- E. the element of local economic activity.

Although there are many intermediate values, which cannot be unequivocally classified to the proper group, their existence points to the urgent necessity for a multilateral, broad approach to economic appraisal of the effectiveness of fish culture.

A. Fish culture in ponds constitutes a significant element of complex water management. It sometimes regulates water conditions over much broader areas than the immediate locality. This applies especially to ponds situated in upper parts of rivers; such ponds can greatly increase the retention capacity, mainly by receiving the surplus of spring water.

As a rule fish ponds, like all small water bodies, constitute part of the so-called "small retention", improving water relations over the neighbouring lands. As a result ground water level is elevated, and the agricultural harvest in the region increases considerably. Furthermore, such fish ponds usually play a role as antiflood reservoirs. Working Party material has shown that in some cases the financial benefits of this non-fishery role can reach 40 percent of the average annual profit obtained from fish production.

It is worth pointing out that several experts in the field of water management are of the opinion that the lowering of the ground water level and decreased humidity in some European regions result from the disappearance of previously very numerous small village ponds in which water was stored for husbandry purposes, as well as of less numerous mill-ponds. Various countries of the world have already started to take steps directed at creating, as far as possible, small water bodies. Construction of such water bodies is usually supported financially and legally by the state, showing that this non-fishery value of fish ponds is mainly of a macro-economic character.

B. The value of fish culture as an element of local management of water resources is more of a micro-economic character, usually being most regarded by the fish farmer. In reality it consists of utilizing (or the possibility of utilizing) the water for other, non-fishery purposes. These include utilization of fish ponds for the breeding of water fowl, watering and washing of cattle, local irrigation of grazing fields, cultivated lands, vegetable gardens and orchards. In many cases fish ponds are also used as anti-fire reservoirs, and sometimes water stored in ponds is even used by local industry and for domestic purposes.

It should be emphasized that several of these values of fish culture can be easily measured. This is especially true of the increase in vegetable harvest due to sprinkling with pond water rich in nutrients, as mentioned by several authors and illustrated in Table 1. This table shows the economic effect of sprinkling vegetables according to studies by the Institute of Horticulture (Kaniszewski and Rumpel, 1976).

Table 1
Economic effects of sprinkling vegetables

Vegetable	Average increase of harvest (%)	Value of increment of harvest (000 zł./ha)	The highest increase of harvest (%)	The highest value of the increment of harvest (000 zł./ha)
Cucumber	13.5	13.4	26.6	18.4
Cauliflower	30.0	13.0	100.0	38.4
Autumn cabbage	18.0	22.0	46.3	60.2
Onion	47.6	15.2	75.0	28.4
Tomato	11.0	10.3	20.0	18.8
Celery	37.0	89.5	70.0	155.6
Leek	21.0	40.7	23.0	61.2

According to data from the literature, water needs for sprinkling vegetables in central Poland amount to 220 mm annually. This amount can be easily taken from fish ponds considering that to obtain an increase in the vegetable harvest of the order given in Table 1 it is enough to take a 22 cm layer of water from 1 ha of ponds. Subtracting the costs of sprinkling devices (N.B., their depreciation time is 1-2 years), the residual value of the increase in the vegetable harvest can be taken as the non-fishery value of 1 ha of fish ponds.

C. As a rule the value of fish culture in the protection, preservation and shaping of the natural environment is most difficult to measure but is also under-recognized. Many authors state that only the retention of water constitutes a significant factor in environmental protection, which automatically implies that in this context the role of fish culture

is of a positive character. It is usually pointed out that fish culture improves the microclimate and buffers excessive changes of temperature, especially on hot summer days. In numerous cases pond fish culture is being developed upon waste lands, or upon areas totally degraded by other human activities (for instance, on gravel pits, peat-bog pits, etc.), thus acting as a recultivation method. Fish ponds create a valuable shore zone (between land and water) which often constitutes a rich habitat for the development of wild fauna and flora wildlife sanctuaries, enriching and variegeting the entropogenic environment. On the other hand, cases are known where fish ponds are also treated as valuable hunting zones, or even as valuable reserves for rare plants and fowl.

However, the highest value of fish culture, and especially of pond fish culture, consists of its role in the control of water pollution. In many cases pond fish culture utilizes organic wastes, transforming them into fish production. This value of fish culture is so significant that numerous authors are of the opinion that it can constitute the main object and aim of promoting the development of fish culture. This problem is discussed also in Part I, Section 1.3. The K_v value of fish culture will in this case be equal to the costs that would otherwise be incurred for the purification of organic wastes plus the profit obtained from fish production. It should be underlined that some intensive forms of fish culture (e.g., cage fish culture) can lead to the situation where this value becomes negative, as the fish culture may pollute waters. It is necessary to take into account this factor in assessing the economic efficiency of fish culture.

D. The value of fish culture in various non-production benefits is not only very difficult to measure, but also difficult to define. Fish ponds are frequently utilized for recreation, and even for water sports. Cases are known where recreational utilization of ponds is clearly in conflict with their fishery utilization. On the other hand, the most intangible value of this aspect of fish culture consists of the most direct contact between man and nature, such as in the high aesthetic value of ponds, especially as regards the landscape. It is no exaggeration to state that modern fish farms are now becoming attractively landscaped enclaves, introduced into and creating equally attractive natural environments.

It is worth mentioning how some authors generalize this value of fish culture in terms of its wholesome effect on the people.

E. The value of fish culture as a factor of local economic activity is extremely high. It consists mainly in the possibility of utilizing waste lands which cannot be used for any other purposes, hence increased land utilization. Fish culture creates new work upon the waste lands and results in a general increase in people's income. As a rule, the high profitability of fish culture compared to other branches of agricultural production significantly increases the economic results of diversified complex farms and stimulates their overall development.

At the end of this section, it is worth mentioning that in numerous cases the non-fishery values of fish culture are realized independently (i.e., at other times and in other places) especially if the fish farm is specialized in the production of stocking material. The rapidly developing recreational fisheries should also be included here, as they are usually based on the production of stocking material in different forms of fish culture. The same goes for the production of stocking material of phytophagous fishes, which are then used for biological control of water weeds. This value is well exemplified by one paper in which the author states (Opuszynski, 1972) that the introduction of grass carp into a channel resulted in the removal of plant mass that "... otherwise would have used the amount of water sufficient for the irrigation of 20 000 ha of cotton fields". In view of increasing thermal pollution, this aspect of fish culture will become more and more significant.

References

See references numbered 3, 5, 8, 13, 16, 19, 32, 33, 38, 55, 58, 64, 68, 82, 91, 94, 95, 97, 102, 103, 107, 111, 114, 118, 120, 128, 133, 137, 138, 140, 142, 148, 153, 173, 175, 182, 183.

Fish culture as ...

... an element of complex water management;

Dudzinski, L., Orłowski, W. (1974); Shpet et al. (1969); Bezdol'nyi, N. (1971); Kucharz, J. (1974); Stangenberg, M. (1974); Semkov, J. (1974); Platek, R. (1977); Shevriin, M. (1976); Wróbel, S. (1979); Szamborski, J. (1967); Hofman, L., Kortylewska, A. (1971); Chizhik, A.K. (1970); Murin, V.A. (1972); Mat. of WP (1974)

... an element of local water resources management;

Dudzinski, L., Orłowski, W. (1974); Wołoszyn, J. (1974); Kaniszewski, S., Rumpel, J. (1976); Shpet et al. (1967); Sizenev, B. (1976); Bezdol'nyi, N. (1971); Anan'ev, V. (1974); Babalan, K., Gordon, L. (1968); Chizhik, A.K. (1970); Murin, V.A. (1972); Isaiev, A. (1975); Mat. of WP (1974)

... an element of protection, preservation and shaping of the natural environment;

Dudzinski, L., Orłowski, W. (1974); Wołoszyn, J. (1974); Shpet et al. (1967); Tarasov, E., Koltypin, J., Francuzova, E. (1975); Prosiannyj, V.S., Makina, Z.A., Francuzova, E. (1965); Bezdol'nyi, N. (1971); Michalik, S. (1974); Platek, R. (1977); Dziekowiński, Z. (1974); Dubel, K. (1976); Witkowska, E. (1976); Wróbel, S. (1973); Opuszyński, K. (1972); Babalan, K., Gordon, L. (1968); Martyshev, F. (1973); Murin, V.A. (1972); Isaiev, A. (1975); Mat. of WP (1974)

... an element of various non-production benefits;

Dudzinski, L., Orłowski, W. (1974); Wołoszyn (1974); Shpet et al. (1967); Michalik, S. (1974); Platek, R. (1977); Martyshev, F. (1970); Anan'ev, V. (1974); Andrzejewski, R. et al. (1973); Babalan, K., Gordon, L. (1968); Murin, V.A. (1972); Isaiev, A. (1975); Mat. of WP (1974)

... an element of local economic activity

Wołoszyn, J. (1974); Mikitei, M., Pollashchuk, V. (1976); Bezdol'nyi, N. (1971); Bautrel, B. (1976); Pavlov, P., Glushchenko, L. (1974); Martyshev, F. (1970); Logenko, M. (1971); Kolkin, S. (1976); Sidorov, G. (1970); Martyshev, F. (1974); Babalan, K., Gordon, L. (1968); Chizhik, A.K. (1970); Murin, V.A. (1972); Mat. of WP (1974)

1.3 Main Types and Methods of Fish Culture

The modern development of fish cultura, and constant efforts aimed at its improvement by a variety of methods and under different conditions, result in an almost infinite number of different types, forms and variants of fish cultura. Current criteria used to define different types of fish culture have become quite insufficient. At the same time, any reliable assessment of the economic efficiency of fish culture is essentially conditioned by the possibility of defining the various forms of fish culture, in order to distinguish different types. On the other hand, a modern approach implies the need to distinguish between different types of fish culture on the basis of different criteria, so as to be able to assess their economic efficiency from a number of viewpoints.

Classification of different types of fish culture on the basis of a variety of criteria is also important from other points of view. First of all, it allows definition of the relationships existing between broadly understood conditions of a given type of fish culture and its economic effects; thus for definition of the most important factors which determine these effects. Secondly, such an approach offers the possibility of avoiding an erratic economic interpretation of apparently analogous types of fish culture, especially in cases where this analogy is based on a small number of too general criteria used for classifying fish culture. To illustrate the point it is possible to cite several cases of such erratic interpretations. Thus, if thermal requirements of fishes are taken as the criterion, we obtain the traditional division into warm- and cold-water fish culture. Hence, in numerous cases conventional trout culture is treated similarly to the fattening of trout using thermal effluents which allow for intensive feeding of fishes during the winter. Similarly, normal pond carp culture is frequently assessed in the same way as carp culture in warm waters, in which the growing season is prolonged by a month or more, depending on the climate (or a similar approach is adopted for the assessment of carp culture in ponds which can and cannot be dried, or with clean and polluted water, etc.). It is obvious that the interpretation of economic results, without taking into account specific conditions of the type of fish culture under consideration, can lead to misleading generalizations.

The most essential criterion for the classification of different types of fish culture and also most significant from the economic point of view, is its intensity, i.e., the division into extensive and intensive cultura. This criterion is commonly used and frequently misused, since the line between extensive and more intensive methods of fish culture is not clear. This criterion always necessitates some definition of the measure of intensity, and also of the type of fish culture and the given conditions. Due to its significance and common acceptance, this criterion must be discussed more in detail.

The level of fish production per unit area is usually taken as the measure of intensity. In most cases this measure is misleading, especially when it is used as the sole criterion. This can be explained by two factors: 1) it does not take into account any effects of natural conditions, which always affect the level of fish production (even when it seems that the conditions are comparable); and 2) it does not take into account the level of means and measures, and hence the most important factor in any assessment of economic efficiency. This measure is especially inappropriate when used on a macroscale. Nevertheless, it can sometimes constitute quite a satisfactory, indirect index of intensity on a microscale, especially if used together with other production, or strictly economic, indices.

It should also be mentioned that a number of authors use fish feeding as the measure of intensity, usually in the case of pond fish cultura.

As a rule fish cultura based on artificial feeding has been treated as intensive; without feeding as extensive. Such an approach is now no longer possible for at least two reasons: 1) rates and methods of feeding are very different, and 2) there are several methods of intensive fish culture that are not connected with feeding, such as aeration, etc.

At present the input (expenditure) of means and measures per unit of area or volume, and/or per unit of production constitutes the best available measure of the intensity of a given type of fish culture under given conditions. In this respect special attention should be given to labour requirements, capital requirements, energy requirements, and material requirements. These requirements are closely connected with the assessment of the economic effectiveness of fish culture (being also characterized by high cognitive value). Assessment based on these four types of requirements is fully applicable on a microscale, and, after proper verification and obvious qualifications, also on a macroscale. For a given scale, all values of these requirements lower than the average can be treated as low, and higher than the average - as high. It should be emphasized that, quite apart from the considerable variety of indices used for assessment of the intensity of fish culture, the distinction between extensive and intensive form is particularly useful in making proper management decisions, and in economic assessment. Such a distinction is in itself valuable management information.

Classification of fish culture according to the requirements of fishes, or by species, is also quite common. We can distinguish here:

fish culture of warm-water species, mainly carp and other species with similar thermal requirements,

fish culture of cold-water species, mainly salmonids, e.g., trout.

The predominance of carp and trout in these two categories results in their being frequently defined as trout culture and carp culture. These names are so common that water bodies (e.g., ponds) used for farming are also defined as trout or carp ponds, although in some cases they are used for rearing different species.

The same type of classification, although more rarely used, is fish culture of predatory and non-predatory species. It is further divided according to the feeding habits of fishes into culture of plankton-feeding, benthos-feeding and phytophagous fishes.

Fish culture can also be divided according to the type of production into that with a full or partial production cycle. In the first case the cycle covers all stages, from spawning to market (table) fish. In the second, it is restricted to some defined stage or stages, for instance, to the production of table fish from stocking material purchased elsewhere, production of specific types of stocking material (fry, yearlings, etc.), etc. Significant specialization of some farms results in the division of farms into those producing exclusively stocking material, and those producing table fish. It should also be pointed out that fish culture of stocking material is highly significant from the viewpoint of economic efficiency of fish culture in general, extending even to marine fisheries.

Length of the production cycle also allows distinguishing between different types of fish culture, from a maximum four-year cycle, to as short as one year or less. In most cases this division is based on the time necessary for the production of table fish; in the case of production of stocking material the cycle is much shorter.

Taking into account the quality of the fish stock one can distinguish fish culture according to the species, age of fish, etc., as follows:

mono- and polyculture. The given water body or other appropriate device is used for rearing one, two or more fish species;

mono- or poly-aged fish culture. One water body holds the stock of fishes belonging to different age classes.

Fish cultura can be also classified according to the type of water bodies (or other devices) used for fish farming. This division is highly justified from the economic point of view. Fish farming in natural water bodies is, as a rule, characterized by much lower capital requirements compared to artificial reservoirs. In the latter case fish culture is always connected with high capital investment for the construction of suitable reservoirs. On the other hand, in view of the rapid development of fish culture, this division, notwithstanding its significance, becomes more and more relative and less clear for the following reasons:

increasingly frequent introduction of expensive measures in natural reservoirs, aimed at the improvement of fish culture. As a rule they create partly artificial conditions in natural water bodies;

rapid development of modern forms of fish culture in various types of cages, nets, partitions, placed in a variety of water bodies, both natural and artificial, independently of the primary use of the given body. Assessment of this form of fish culture has significant economic implications.

It follows that correct designation of water bodies constitutes another criterion of the classification of fish culture and there are three basic situations:

fish culture in water bodies especially constructed or adapted for this purpose. Fish culture constitutes here the main production;

fish culture in multipurpose water bodies, where the production of fish is just as important as other functions of the reservoir;

fish culture in water bodies designated for a totally different purpose. Fish culture constitutes here a specific by-production, merely supporting the main purpose of the reservoir.

In the first case fish culture should bear all the investment costs of the construction of the water body; in the second, it should partly cover the costs; whereas in the third case it should not bear any costs, and sometimes should even be subsidized by the main user.

The above division is connected with another classification, based on the scope of fish culture. In this context 7 types of fish culture are commonly distinguished:

culture for food production;
culture to improve natural stocks through artificial recruitment and transplantation;
culture for the production of sport fish;
culture of bait for commercial (sport) fishing;
culture of ornamental fish;
culture for the recycling of organic wastes;
cultures for industrial or other similar purposes.

It seems unlikely that this classification can comprehensively cover the whole problem. From the viewpoint of economic assessment of fish culture it would be most desirable to divide fish culture into that aimed at either fishery production or at some other non-fishery purposes. The former type should be divided again into the form which is aimed at maximal profits and the form aimed at maximal production. The latter type is especially significant in the case of fish culture for food production.

Taking into account the system of water supply to the culture units (e.g., ponds), we should distinguish fish culture based on ponds with or without independent inflow and outflow

of water. In the first case each pond can be filled and dried independently of the other; in the latter the ponds possess a direct contact via the water, e.g., filling or draining always occurs through some other pond (chain system).

As regards the possibility of drying the ponds, we can distinguish between fish culture in drainable and undrainable ponds. Drainable ponds are further divided into those that can and cannot be totally dried. The latter difference might seem unimportant, but in reality it plays a significant role. Ponds that can be totally dried are usually subject to various agricultural measures, and can periodically be used for conventional agriculture. This difference is also reflected in another form of fish culture, i.e., with alternating utilization of ponds (rotation system) where ponds periodically are used for fish production, and periodically for plant production. It should be underlined that as regards the filling and draining of ponds, there is in practice a whole variety of fish culture types. The most important are: multi-year utilization of ponds without draining and two other forms differing as regards the period of filling the ponds with water (i.e., spring and autumn form). The multi-year utilization of ponds is very interesting since, as a rule, it is connected with fishing methods typical for conventional fisheries, and thus from an economic point of view it differs from other types of fish culture. This variant is most frequent in cases when a fish culture project is short of water, or when ponds serve for other general purposes (unconnected with fish culture) and cannot be left without water. Some authors point to the fact that this type of fish culture improves the fertility of ponds and thus decreases the cost of fertilization. However, this view seems questionable due to the fact that intensive fish rearing results in an accumulation of metabolic products. At present there is a tendency to remove these products through water flow, even for species that under natural conditions do not require such treatment (e.g., carp). Thus water flow constitutes another criterion for the classification of fish culture into fish culture in either stagnant or flowing waters. It should be underlined that in the case of intensive fish culture water flow is frequently connected with the necessity of maintaining proper water quality in the body receiving the outflow from the ponds.

The necessity of preserving proper water quality is also linked to another division into two more forms of fish culture, i.e., in opened and closed circulation systems. In the first case water is used only once and then discharged into the receiving water body, whereas in the latter it is used repeatedly, with interim treatment.

The nature of water used for fish culture, especially water quality, constitutes another criterion for distinguishing different forms of fish culture. As regards inland water, the basic division currently used is between fish culture in clean and polluted waters, the latter being divided into waters polluted with organic wastes and thermally polluted waters. Thermally polluted waters are closely connected with the most modern form of fish culture in tanks and cages. This form is currently characterized by an extremely rapid development, spreading over a variety of waters and fish species, and becoming increasingly important from an economic point of view, although its effects are frequently debatable.

As has been shown, a number of different forms of fish culture can be distinguished according to the criteria adopted. It must however be stressed that in practice different forms of fish culture can occur together and overlap so that the boundaries between them are not clearly defined. Consequently, we must always bear in mind that each economic assessment, even if it takes into account the most essential criteria for the form in question, will always be somewhat relative, so that in many cases even small differences in conditions, biotechniques, level of intensity, or different means of intensification significantly affect the economic results of fish culture.

The above statement does not, of course, obviate the need to undertake economic assessment of different forms of fish culture, but it points to the importance of introducing several additional indices apart from those typically used in economic analysis.

Reference

See reference numbered 41.

2. SIMPLIFIED MODEL OF FISH CULTURE PRODUCTION AND ECONOMICS

Due to the specific characteristics of fish culture (see Part 1, Section 1.1) it is extremely difficult, and sometimes even impossible, to propose methods of economic evaluation that would be comparable and applicable to different forms of fish culture, and still remain valid for economic accounting (i.e., that would unequivocally relate the results of fish culture to its costs).

This situation can be well illustrated by a simplified working model of fish culture production and economics (Fig. 1). This model assumes that it is impossible to establish one universal method of economic accounting and analysis for all forms and different conditions of fish culture. Furthermore, the model points out that in order to fulfil the criteria of reliability and comparability, economic accounting must include several indices which are not usually included in classical economic analyses.

Fish culture and its management and hence its economic effectiveness, which constitutes the subject of economic analysis, is determined in the first place by complex sets of various factors. These factors determine and define the set of management factors (given managerial decisions, adoption and allocation of proper means, measures and methods) and hence also the final results of this management (Fig. 1). In the attached model (Fig. 1) four sets of such factors are presented and will be discussed briefly.

2.1 Set of Natural Factors

The best example of these factors are geographic and climatic conditions. Although they represent those factors which most significantly affect fish culture and its results, along with the more commonly known factors, they are rarely included in economic analyses of fish culture. It is a striking illustration of the hiatus existing between those who are directly involved in fish production and those who are involved in its economics and evaluation.

The effect of these factors on fish culture production is well illustrated by Vavruska (1972). This author states (on the basis of studies carried out in Czechoslovakian carp farms) that the "basic growth increment (of carp production) is lower up to 26.4 kg/ha at an altitude higher by 100 m, and greater by 66.7 kg/ha in a locality warmer by 10°C". In Czechoslovakia classification of ponds according to different natural conditions was developed by Vacek (1969). Temperature, precipitation, soil classification and altitude were taken into consideration, and the ponds were divided into 7 groups.

Studies by Worniallo (1977) showed that in Poland the average, multi-year differences in carp production in farms with the greatest difference as regards the temperature during the season vary between 34 and 84 kg/ha, depending on the level of intensification: the higher the intensification the more visible the effect of temperature.

According to Hickling (1962) fishes reared in Europe have "... only about 180 days of growth annually" while "... in Israel there are 220-240 days of intensive growth during warmer months, and 120 days in cooler months when growth is smaller".

According to Krupaer (1973) the growth period in Czechoslovakia lasts for about 6 months, while in Yugoslavia - as stated by Apostoloski and Arsovski (1974) - by at least 2 months longer. The production and economic consequences of these facts are obvious.

These consequences are illustrated by a table presented by Murin (1972), referring to different climatic zones of the Soviet Federation in 1969 (2-year production cycle) (Table 2). Discussing this table the author poses a question as to the rentability of production in different climatic zones if we assume that fixed capital is similar everywhere.

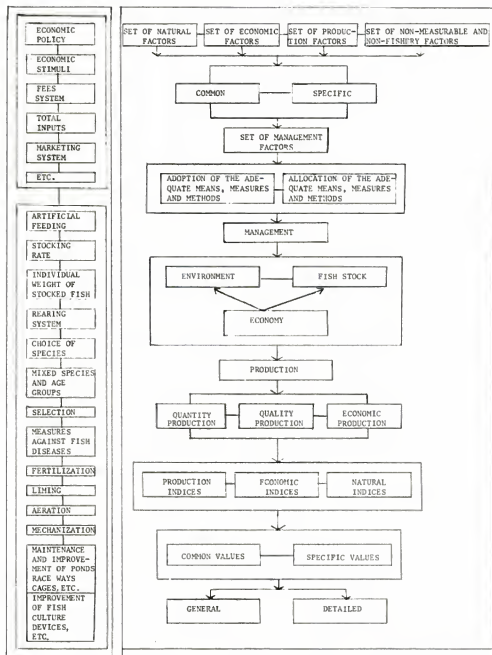


Figure 1. Simplified model of fish culture production and economics

Table 2

	Climatic zone		
	Southern	Moderate	Northern
Stocking rate indiv./ha	5 818	3 860	2 635
Individual weight of market fish in g	431	369	282
Production in kg/ha of fattening ponds	1 487	1 024	386

Other factors belonging to the set of natural factors which are not usually taken into account in the evaluation of fish culture economics are the fertility of the catchment area supplying the ponds with water and hydrological conditions as stressed by the members of the Working Party (Apostolski, Arsovski, 1974; Leopold, Kozun, 1974; Polish Case Study No. 6, 1975). Effectiveness of fish culture in conditions of water shortage, both as regards water resources as such and the supply of clean water, will be totally different. It is worth pointing out that in many cases problems of hydrological conditions are reflected after a fashion in economic accounting, mainly under the item "fees for water". On the other hand, however, the lack of such an item does not necessarily mean that a fish farm does not in reality face this problem.

As stated by Leopold and Kozun (1974) due to water shortage "... many pond complexes do not, in practice, fulfil the demands of a rationally managed fish farm, but for understandable reasons (see Part I, Section 1.2) their liquidation cannot be considered.

The above natural factors are usually closely connected to the availability of land and relief. The latter problem has been raised by Apostolski and Arsovski (1974). The location and size of production units of fish culture are determined, to a large degree, and sometimes decisively by these factors. This, in turn, influences the effectiveness of production and its economics. The effect of size of production units on the economics of fish culture is discussed in another section of this paper.

2.2 Set of Economic Factors

The most important economic factors are the general, social and economic system in which fish culture is operating. Thus we can distinguish here between the economic system which is more or less centrally planned and systems with a relatively free-market economy. In the case of fish culture these differences are connected with several legal aspects such as ownership, possibilities for promoting or limiting the development of fish culture, possible conflicts with other land and water uses and users, problems of environmental protection, etc. The effect of these factors on the economics of fish culture (Polish Case Study No. 1, 1974) may be significant and, in the case of particular farms, may even be decisive.

The role of fish culture in the national economy or in the economy of the given region:
The problem consists mainly of the role of fish culture in protein production and its efficiency compared to other forms of production. Numerous economic indices involved here are analysed in detail in other sections of this paper.

Particular economic and management situations which determine the operation of fish culture:

This problem is practically restricted to the availability or lack of certain resources necessary for the proper operation of fish culture, namely, capital, material, energy, land, labour and finally "know-how". In certain cases some of these resources are substitutional; in others they are not. In both situations, however, their effect on the management of fish culture and its effectiveness would be significant, sometimes even decisive. This may be well exemplified by the problem discussed by Krupaer (1973). This author argues the common view that pond fish culture in Czechoslovakia is mostly of an extensive nature, and states that "... the analysis of results from other countries indicates that the main method of intensified fish culture is feeding, i.e., direct application of complete, often high-cost industrial feeds. Czechoslovakia cannot use this method because of unavailability of sufficient supplies of such feeds. Experience with intensified pond fish culture indicates that if feed rations similar to those used in other countries are applied, we can almost immediately increase production per ha two or three times in half our ponds".

It is worth pointing out that particular economic and managerial circumstances; as described above, sometimes lead to dramatic improvements in the efficiency of production and even to the creation of totally new forms of fish farming.

2.3 Set of Production Factors

When stating that a given fish farm "has favourable or unfavourable conditions of production", we refer to those factors which are directly connected with production. Compared to previous sets, factors belonging to this set are less general and their effect is usually limited to a defined scale, although they can significantly affect fish culture and its efficiency. Indeed as a rule, these factors unequivocally determine the type and method of production, its scale and limits, costs, and finally also its economic effectiveness. Production factors, or conditions of production, are usually connected with the above-mentioned natural and economic factors, as well as with the non-measurable and non-fishery elements of fish culture.

A typical example of an important production factor is the size of ponds, pond complexes of the given farm and their position or scatter. The economic implications have been pointed out in the materials of the Working Party (Leopold, Kozun, 1974; Leopold, 1974; Vacek, 1970; and others).

Apart from the problem of the size of production complexes of fish culture, which is discussed separately, it seems advisable to cite some conclusions given in the paper by Vacek (1970):

"... The distances of ponds from fish farms ... can be characterized as the most important factor ... affecting economic efficiency of fish production". This conclusion results from the correlation: a) between growing distance and diminishing intensification of production, b) between growing distance and increasing costs of transport, overhead charges, etc.

"... The size of ponds ... has the highest partial impact on the share of labour costs in fish production".

"... The average distance of 1 ha (an index introduced by Vacek) from fish farms has the greatest partial impact on the share of direct costs in fish production".

Another production factor is the quality of ponds. Its impact on the economics of fish culture was underlined by Leopold and Kozun (1974). Attention was also drawn to the fact that in many cases fish culture was still operating on ponds built in the Middle Ages, obviously a limiting factor. The same is true of the German Federal Republic and Czechoslovakia. Krupaer (1973) states that: "... Among the negative factors affecting our fish culture establishments is the fact that most of the ponds are 300-400 years old or even more. They were established under completely different production conditions and many of them no longer meet the present requirements for modern pond management (unsuitable depth, bottom size, location in landscape)".

The problem of fish culture in so-called undrainable ponds also belongs here. Efficiency of this type of fish culture, in comparison to fish culture in drainable ponds, is usually much lower. This is exemplified by Table 3 based on Grobokopatel (1976).

Table 3

Group of farms	% of drainable ponds	Production in kg/ha
I	5.2	209.2
II	35.9	386.3
III	62.5	654.7

Lower efficiency of fish culture in undrainable ponds, compared to drainable ones, is even more evident from Table 4, based on data given by Murin and Grobokopatel (1968).

Table 4

Group of farms with production in kg/ha	% area of drainable ponds	Value/ha of pond construction in %	kg of production/ 1 000 rubles of pond value in %	FCR in %
up to 200	15.3	100	100	100
200-400	60.3	158	157	122
400-800	84.9	210	236	112
over 800	94.9	257	361	107

Although use of undrainable ponds reduces the capital investment (by lower cost of pond construction), it also yields much lower production and thus lower profitability of the investment. Furthermore, it increases the operating costs due to the increased amount of feeds needed for fish production. This is because of the relation between the increase of feed use per unit of production and the increase of production in farms with lower number of undrainable ponds.

It is not possible to discuss in this paper the whole variety of significant production factors. Nevertheless, those that can be discerned must be incorporated into the economic analysis, or at least discussed explicitly.

2.4 Set of Non-measurable and Non-fishery Factors

The effect of these factors (see also Part I, Section 1.2) frequently determines not only the efficiency of fish culture, but even its very existence. The growing importance of these factors stems from the fact that frequently fish culture interests are subordinate to the interests of other (official or unofficial) water users, or even to more general economic aims. In other words, fish culture meets particular situations and must operate within them. Generally speaking, it is possible to distinguish here the following situations:

restriction or limitation of fish culture due to the utilization of its production base for some other purposes or to environmental protection, agricultural interest, water management, fisheries in open waters, etc.

stimulation or promotion of fish culture - due to the same reasons as above.

There is no contradiction here. For instance, in one case an increased water level may be favourable for fish culture but unfavourable for agriculture (flooding of arable lands), while in another case it might be equally favourable for both interests due to the higher level of ground waters.

It is worth mentioning that in general any limitation placed on fish culture has a deleterious effect on its operations and creates various difficulties in proper management. However the stimulation and promotion of fish culture does not necessarily increase its efficiency or facilitate management because of the specific role played by fish culture.

The four sets of factors are interrelated, and their classification is made only to show the complex problem of objective conditions or factors at the basis of fish culture, and to underline the necessity of taking them into partial or full consideration in any economic analysis of the efficiency of fish culture. Some of the factors are universally found in each form of fish culture, no matter where it is operating; others are specific for certain forms of fish culture, and thus are treated as specific factors (Fig. 1). For example, everywhere and in each type of fish culture (apart from ultra-modern methods of industrial fish production), we have the effect of climatic conditions; notably, temperature; fish culture is a producer of animal protein wherever practised and, hence, can be compared to other methods of protein production; fish culture operations are always dependent on the availability of certain resources connected with the size of production units, their quality, etc.

Both common and specific factors determine and define the selection of managerial decisions necessary in a given situation, together with the adoption and allocation of adequate means, measures and methods through which the management of fish culture can operate, and thus also the nature of our impact upon an integrated production system comprising environment (fish stock) farming (Fig. 1). Means, measures and methods constitute in practice the basic items of economic accounting and the elements of fish culture intensification, affecting the appropriate indices of economic evaluation. Each of these elements results in a measurable economic effect on the results of fish culture, although their impact is of a complex nature. As a rule, each of them can be distinguished and hence should be the subject of economic analysis.

Whether the objective of fish culture is quality, quantity or profit, any economic assessment of production must be based on proper economic indices coupled with production indices. The latter are both inseparable from economic indices and indispensable for reliable assessment. As shown in Fig. 1, this stems from the fact that fish culture and its management constitute a very complex system, with numerous interrelated and diversified variables, the effect of which must be taken into account in order to obtain a feasible economic assessment. The above statement can be illustrated by an example based on Table 16. Two groups of farms analysed in this table possess totally different indices of effectiveness of fish culture at similar operating costs per 1 ha. This fact would be incomprehensible if economic indices were the only ones used in the analysis.

The criterion of purpose to which fish production is put (i.e., differentiation of fish production in respect of its level, quality and value) calls for an explanation. This differentiation is quite important from the standpoint of assessing economic effectiveness.

In extreme cases we can have three different situations, depending on whether the decision maker prefers:

maximal level of production, relatively independent of its quality and costs;

maximal quality of production (species or combination, etc.) relatively independent of its level and costs;

maximal profit, relatively independent of the level of production and/or its quality and costs.

The decision makers are not only the fish farmers themselves but also (especially in the first two cases) their superior managers, institutions, organizations, and especially some national bodies (or government), which exert significant pressure on the producer in order to obtain the preferred production. Such situations, which approach the extremes described above, are quite common, especially in cases when fish culture constitutes merely an instrument of some economic policy on a macro- or micro-scale.

In view of the above, it is vital to incorporate all indices into the assessment of economic efficiency of fish culture (i.e., both those strictly economic as well as production and natural ones) together with the various objective factors which constitute an indispensable background for those indices. The indices used may be common, which as a rule are universally comparable or specific, which are comparable only under particular situations and circumstances; moreover, they can be of a general or detailed character.

References

See references numbered 53, 54, 80, 87, 107, 109, 156, 157, 164, 181, 188, 193, 196.

3. GENERAL REMARKS ON METHODOLOGY

Assessment of the economic effectiveness of fish culture can be carried out from several points of view and with varying precision, depending on the needs and scope. It is appropriate to make such an assessment on two levels: macro- and micro-economic. This problem has already been underlined by Dabrowski (1972).

As stated by Dabrowski "... economic macroanalysis serves as a basis in determining production policy of the country". At this level of analysis "... two main tasks that should be undertaken" were distinguished:

- (i) Establishment of the level of such economic criteria as: costs per unit of production, efficiency of work and effectiveness of investments.
- (ii) Finding out the possibility of reducing costs and improving the other criteria.

Further on this author states that "... such tasks would make it possible to find out the cost of fishes in comparison to other protein products, and to continuous improvement of all other criteria, especially the efficiency of work".

According to Dabrowski "... microanalyses refer to economic analyses of all fish culture enterprises, which would help to improve the production. Such analyses apply, of course, separately to different fish farms".

This essentially correct methodological approach necessitates some more precise definition and discussion.

Basically, analysis of the efficiency of fish culture on a macro-economic level must fulfil two essential purposes, as follows:

(i) It should give premises and arguments justifying and explaining the scope, need, direction and ways of promoting and developing fish culture at an international, or at least local, level to be used by appropriate organizations, institutions, authorities or managers undertaking decisions at this level. This type of analysis is clearly connected with the general role of fish culture viewed as a producer of food for human consumption, especially proteins. It should be coupled with the assessment of profitability of fish culture compared to other forms of this type of production, but also with the specific economic value of fish culture on a macro-economic scale.

The macro-economic approach is well illustrated by a small note on the programme for development of fish farming in Bangladesh (March 1978 issue of Fish Farming International, p. 4). Two sentences are worth citing, i.e., "... that a 40 000 t increase in production is expected by 1984", and that "... the programme will create 6 000 new jobs and involve 2 000 fish farmers".

Another example, connected with the specific role of fish culture, is a statement by Krupaer (1973) explaining that one of the motivating factors for the renovation and construction of pond complexes in southern Moravia (an area with water shortage) was to increase water retention in this area. The same author (Krupaer, 1973) explains the present direction of the development of pond carp fish culture in Czechoslovakia resulting from the shortage of high value fish feeds.

(ii) It should constitute a background for the analysis of fish culture on a micro-economic level. Even crude analysis of the efficiency of fish culture on a macro-economic level should reveal the existence of some specific, "initial" elements which influence further development of fish culture. These elements affect the results of fish culture and its final economic efficiency even on a micro-scale (e.g., in particular fish farms) and should therefore be taken into account in an analysis made on this level.

To illustrate the point let us assume that in some country the national economy favours the development of one specific form of fish culture, at the same time limiting the development of some other form. Any economic analysis of the efficiency of both forms that ignores this fact would certainly lead to totally false conclusions. Thus if some form is favoured by the authorities, there may be direct or indirect promotion and such specific "initial" elements represent partly "objective" factors in the previously discussed model.

Even considering only these main aims of economic analysis on a macroscale, it is possible to draw several conclusions regarding methodology:

a. Economic analysis on a macroscale should be sufficiently general, based possibly on general indices, so as not to get lost in details. For example, from a macroeconomic point of view it is significant to possess such information as given in Polish Case Study No. 1 (1974), i.e., information on the forms of protection for fish farms in Poland and its role in the development of fish culture. On the other hand, it would be quite absurd to discuss the details of at least 5 different forms of subsidizing fish farms in Poland. Similarly it is worth knowing that in some countries most farms are of a particular area (for instance, large, amounting to some hundreds of hectares while as the statement that in such countries there is 1 percent of small farms and 2.39% of very large farms would only blur the real picture of fish culture in these countries.

b. At each stage of the analysis maximum advantage should be taken of the most frequently occurring values (indices, measures, etc.). For instance, we can omit an index of pond fish catch per 1 ha of 1 m deep water and simply use catch per 1 ha. Such common indices of the rentability of capital investment and operating costs can be complicated almost infinitely, but for what?

c. Values (indices, measures, etc.) characterizing the specific role of fish culture should be strongly emphasized, especially those which can significantly affect its economic efficiency. For example, if fish culture utilizes water bodies constructed for some other purposes (such as regulation of water resources) and its main impact is to decrease the costs of investments and exploitation of such water bodies, any assessment of its economic efficiency should pay attention to this fact. Furthermore, methods of assessing the effectiveness of this type of fish culture should be different from those used for assessing fish culture created and developed only for fish production.

On a microeconomic level economic analysis of fish culture should embrace analyses both of particular fish culture enterprises (as postulated by Dabrowski, 1972) and of particular elements affecting the intensification of fish culture.

The latter approach integrates the macro- and microeconomic levels and is aimed at a clear demonstration of the economic effectiveness of particular intensification measures in fish culture. For example, such analysis may deal with the effect of feeding, fertilization, different time of pond stocking, etc., upon the economics of fish culture in different conditions and situations.

Adoption of this dual approach to economic analysis is linked to the various purposes for which microanalyses are undertaken. And thus:

- (i) On the basis of detailed analysis of economic efficiency, microanalysis can demonstrate (especially to the fish farmer) the value of fish culture as such, in particular, the optimum forms for the given conditions and situation.
- (ii) On the basis of an analysis of different production measures and intensification means, microanalysis can demonstrate (especially to the fish farmer) the opportunities for improving fish culture in the given conditions and situations.

- (iii) Microanalysis is aimed at defining appropriate indices for making comparisons (especially by the farmer) between the effects of a given fish culture and the effects of other forms of fish culture (e.g., as regards the biotechniques, intensification measures, conditions, etc.).

Comparability of particular elements involved in an analysis of the effectiveness of fish culture at every stage, from the basic source data to final indices, creates serious methodological difficulties due to three main reasons:

- (i) Great variety of different forms and methods of fish culture.
- (ii) Extreme variety of conditions under which fish culture operates.
- (iii) Diversity of methods for economic accounting used in fish culture.

These reasons necessitate the use of production and natural indices along with the economic ones in any analysis of the economic effectiveness of fish culture. The same conclusion also stems from the previously discussed model of fish culture production and economics.

Examples of adopting such an approach, and of the factors which should be taken into consideration in analysing the economic efficiency of fish culture, constitute the main part of this paper.

References

See references numbered 26, 80, 187, 193.

4. GENERAL ROLE OF FISH CULTURE

The general role of fish culture (especially the pond type) as a producer of goods for human consumption, mainly proteins, which are in short supply on a world-wide scale, does not need any particular discussion. Rabanal and Shang (1976) state that "... it is estimated that 3.7 million t or 75 percent of the world production through aquaculture, covering 2.3 million ha or 90 percent of total area used for aquaculture, is derived from this type of system. It is also estimated that pond culture for finfish has stimulated an investment for capital expenses equivalent to US\$ 3 500 million. Furthermore, the potential for increased production from this sector is very high (Ling, 1973). It is estimated, for example, that in Southeast Asia alone there are about 22 million ha suitable for development of ponds for finfish culture".

It can be assumed that this dominant role of pond fish culture will be maintained even when (according to the forecast for the year 2000) aquaculture produces about 50 million t of animal protein (Report of the TAC Working Group, 1973; Webber and Riordan, 1976). Taking into account the growing role of fish culture and forecasts of its further development, two general trends can be distinguished. Each is characterized by economic implications, which are rather important for proper assessment of the economic efficiency of fish culture. In the simplest way these trends can be outlined as follows:

"industrial" fish culture, characterized by a lack of integration as regards the ecological environment, based entirely on artificial feeds supplied from outside and also produced by industrial methods;

"agricultural" fish culture, characterized by integration with the ecological environment, attempting to use as much as possible the natural resources of this environment, mainly through the adoption of measures stimulating the development of these resources.

The economic implications of these two types can be formulated as follows:

agricultural forms of fish culture can operate and be economically effective both intensively and extensively, whereas industrial fish culture can only operate intensively;

agricultural forms of fish culture can operate even on a small scale, while industrial forms usually operate on a large scale;

agricultural forms of fish culture are characterized by relatively low energy, material, and capital requirements, and higher labour and land requirements, whereas the opposite is true of the industrial forms - with lower labour and land requirements, energy, material, and much higher capital requirements;

initial investment and operating costs of the agricultural form of fish culture, are usually lower than in the industrial form. The same applies to the costs of intensification;

non-production value of the agricultural form of fish culture is usually beneficial and can be imputed as "benefits" in economic appraisal, while in the industrial forms it is usually negative and represents "costs". This fact should be taken into account in assessing the economic effectiveness of both forms.

References

See references numbered 41, 121, 168.

4.1. Comparison of the efficiency of fish culture with other forms of animal production

The efficiency of fish culture in comparison to other forms of animal production should be viewed from different standpoints, depending on the situation and needs. Generally two approaches can be distinguished, i.e., "natural" and "economic" efficiency. Both differ significantly; the first approach is independent of prices and is based on natural indices, and hence to a large extent, is comparable and easily understood, while in the second approach respective indices are expressed in monetary units. Consequently, the latter indices cannot be used on an international scale, although they are of significant value on a national scale. To illustrate the point: it is possible to compare (directly or by calculation) production of 1 kg of fish meat and warm-blooded animals per 1 kg of feeds, independently of the country concerned. On the other hand, it is very difficult, if not impossible, to compare the same production in monetary indices due to problems of comparability, with generally incomparable and - as a rule - unstable fluctuating prices of fish and feeds in different countries. However, knowledge of the efficiency of fish culture in a given country or region compared with other forms of animal production, expressed in financial indices, constitutes an especially valuable element of economic policy toward fish culture.

4.1.1 Efficiency of fish culture expressed in natural indices

The comparative efficiency of fish culture, expressed in natural indices, can be analysed from different points of view. The most important and traditionally used consist of an analysis of the efficiency of utilizing a given area for fish culture compared with other possible uses of this area for animal production, and of a comparative analysis of feed utilization in fish culture and other forms of animal production. In both cases this efficiency may be viewed against the level of fish culture production and/or its increase as compared to other forms of animal production, with proper consideration being given to its calorific value, and in particular the amount of proteins produced.

4.1.1.1 Utilization of feeds in fish culture and other forms of animal production. Beginning with vague statements that "... fishes - as it is known - exceed cattle and pigs with respect to the utilization of feeds" (Krasavcev, 1975), and ending with more detailed studies of this problem, there is general agreement among experts in this field that the efficiency of utilizing feeds in fish culture is at least the same or better than in other forms of animal production (Wrobel, 1975; Tal, 1974; Vacek, 1974; Shpet, 1972; Polakov, 1957; Babaian and Gordon, 1968; Gordon and Erman, 1973; Lovell, 1976a, b; Sergeev, 1977).

According to Gordon and Erman (1973) a unit of concentrated feeds used in fish culture gives 88% higher commercial production, and 75% more consumable proteins than in other forms of animal production.

The largest amount of comparative data in this field deals with carp.

According to Polakov (1957) carp production on feeds is 2-2.5 times higher than that of cattle, 1.5 times higher than that of rabbits, and 1.3 times higher than that of pigs. Increase of protein production per unit of comparable feed is, in the case of carp, twice as high as for cattle and sheep, 1.5 times higher than for pigs, 10-20% higher than for chicken, and only 10% lower than for rabbits. Respective indices for carp in comparison to the production of proteins in milk and eggs are also more favourable. As regards calorific value, carp is characterized by 20-40% higher indices than cattle, sheep, rabbits and chicken, 30% lower than for pigs, 40% higher than in the case of egg production, and 30% lower than for milk production. Taking into account the fact that the calorific value of pork meat has a disproportionately high fat content, and also that in the case of milk production no attention is paid to the amount of feeds used for the production of milk cows, even those indices more favourable than for fish culture are not so clear-cut.

Apart from the fact that the above cited data are 20 years old, and that in the meantime, the biotechniques of fish culture and animal breeding have improved considerably and respective indices of feeds utilization per unit of protein production, etc., have decreased, the favourable relationships of fish culture compared to other forms of animal production were not only left unimproved, but even improved. This emerges clearly, for instance, from data given by Wrobel (1975). Production of carp is more effective even in comparison to the most effective as regards the utilization of feeds in large commercial poultry farms. According to Wrobel (1975) 2.5-3 kg of feeds are used to produce 1 kg of poultry, while with intensive carp culture the equivalent feeds amount to 2 kg or less.

It should be noted that this does not apply only to intensive forms, but also to almost all cases when fish culture utilizes natural food resources along with artificial feeds. Thus the efficiency of cattle feeding in comparison to carp in practice is "... 25-50% lower than in case of other live stock" (Wrobel 1975). Moreover, the question of the potential for the decreased use of feeds in fish culture remains open; it is not possible to cite here the abundant literature on the subject, but illustrate the point, some significant examples are worth mentioning. According to Bekos (1976) purely as a result of selection, a carp hybrid was obtained which uses 15-30% less feeds than normal carp for the same weight increment. Kostikov (1975) states that the increase in the individual weight of stocking material from 25 g to 50 g allowed for a decrease in the use of feeds by 16.7-21.4%. Saberslich and Beuer (1975) decreased the use of feeds to 1.64 kg per 1 kg of production as a result of pond aeration. Szumiec (1974) stated that "... by deepening the knowledge on the problems of intensive fish culture, and especially on proper stocking rates improvement of feed quality and feeding biotechniques", the feeding coefficient was decreased by half, i.e., to 2 kg of feeds per 1 kg of carp production. It should be emphasized that during this experiment the use of proteins per 1 kg of production was also significantly lowered, in one case by over 40%.

Recent rapid developments of various forms of fish culture and the constant improvement of traditional methods increase the possibilities of lowering feed requirements per 1 kg of fish production. It should also be pointed out that very often, feeds used in fish culture consist of waste products, which can be effectively utilized practically only in this way. For the general managers and decision-makers this fact is of great economic significance, whereas for farmers, especially those undertaking fish culture as a by-product on a relatively small scale, the problem of the efficiency of feeds fed to fishes (in view of the lack of their alternative utilization) can be very much of secondary importance.

Better utilization of feeds compared to animal production was also noted in the case of channel catfish culture (Lovell, 1976b). Special attention was drawn to the much lower energy requirements of fishes compared to warm-blooded animals (Lovell, 1976a). The author explains that this is caused by three factors: "... 1. fish do not have to maintain a constant body temperature, 2. fish require less energy for muscle activity to maintain their position in water than animals on land, 3. fish require less energy to excrete nitrogen products than warm-blooded animals".

Utilization of feeds in polyculture is most probably at least as effective as in the case of carp since this form of culture is always partly based on natural food resources. A different situation is noted in the case of predatory species, especially salmonids. Due to the need to include high level of animal protein in salmonid feeds, their utilization is most probably less effective, or at most the same as in other forms of animal production.

4.1.1.2 Utilization of land area in fish culture and other forms of animal production. With regard to the efficiency of utilization of feeds in fish culture, as compared to other forms of animal production, we encounter both very general (Duvigneaud, 1975) as well as more detailed (Vacek, 1974; Shpet, 1972; Gordon and Erman, 1973; Murin, 1967) statements on the relatively higher efficiency of utilizing land for fish culture in comparison to animal production on the same area. Methodologically the problem is extremely complicated due to the fact that it is closely connected with the problem of feed utilization and soil fertility (the more intensive the fish culture, the more it is based on artificial fish feeding).

A frequent methodological mistake which should be pointed out here is the direct comparison between the level of fish production per unit of area and the level of warm-blooded animal production which could be attained from the same area (Murin, 1967). Most frequent errors comprise of either the overestimation or underestimation of the efficiency of fish culture as compared to other forms of animal production.

In the first case no attention is paid to the rather obvious fact that feeds used in fish feeding must have been produced on a given area of land; in the second case it is not taken into account that soils on which pond fish culture is carried out are generally poorer than the surrounding lands (Kozun, in prep.), or even on total wastelands.

In reality, when calculating fishery production it is difficult to include the additional area on which feeds are produced. Opinions on this subject vary. According to Vacek (1974) 1 ha of fish ponds should be enlarged by 0.3 ha used for the production of fish feeds. According to Shpet (1972) the additional area amounts to 1 ha, while according to Murin (1967) to 2 ha.

This question remains open (as does the problem of comparison between the efficiency of land-area utilization in fish culture and in animal production) the more so since the calculation necessitates that at least of few parallel factors be taken into account, i.e., level of intensity of fish culture, level of intensity of feed production, level of intensity of other forms of animal production, and finally - fertility of soils and ponds. All this is connected with the efficiency of utilizing feeds, as well as with the economics of fish culture and other forms of animal production. On such considerations it would seem erratic to use more general data, embracing the whole country or its large regions. The data should rather be restricted to specific local conditions. As was proved by the studies of Kozun (in prep.), ponds are usually situated (even in regions rich in fertile soils) on much poorer soils.

As regards the level of production of animal protein, fish culture is one of the most effective forms. Duvingeud (1975) states that: "... in regions with poor soils, well managed fish culture can give much more animal protein per given area than animal breeding on grazing lands of the same area". According to Shpet (1972) in average USSR conditions, carp culture gives 5 times more proteins per 1 ha than cattle breeding. The same author states that in totally extensive culture (without feeding and fertilization) the amount of protein will be respectively 3 times higher. According to Vacek (1974) average production of proteins per unit area in fish culture is very comparable to their production in all forms of animal production.

According to Gordon and Erman (1973) in the conditions of the Soviet Federation, just the natural productivity of 1 ha ponds gives 87% higher production and 76% more edible proteins than 1 ha of land used for animal production. The above cited authors emphasize two facts hitherto insufficiently considered, i.e., that:

- (i) Fish culture utilizes mainly waste-land for its production and refuse as feeds (Shpet 1972), and
- (ii) The basis of fish culture production, i.e. ponds, possesses several non-fishery values which very much increase its efficiency as compared to other forms of animal production (Vacek 1974).

As regards polyculture it usually gives better production than monoculture, and hence its efficiency is beyond doubt.

Attention should also be given to predatory fish production, and above all to the intensive production of trout. It is well known that trout culture usually gives very high yields per unit area. Hence, it would seem that it cannot be compared to any other form of animal production. Nevertheless, it should be remembered that trout feeds are very rich in animal proteins, and that these proteins must have been produced somewhere, - most frequently on

some other water area. Consequently, we should adopt here the same approach as in the case of carp culture, i.e. proper economic assessment should take into account the area needed for the production of trout feed components. The results of such an approach are quite surprising, and the real efficiency of trout culture becomes at least questionable.

To illustrate the above statement let us assume that from 1 ha of trout farm 30 t of fish are harvested, and that in order to produce 1 kg of trout 5 kg of other fish are needed (Weatherly and Cogger, 1977, state that 8 kg are needed to produce 1 kg of predatory fish). Hence, to obtain 30 t of trout per ha it was necessary to use 150 t of other fish. Assuming that the productivity of natural waters from which these 150 t were obtained amounted to 100 kg per ha (rather high for natural waters), in order to produce 30 t of trout per 1 ha it was necessary to use an extra 1 500 ha of other waters. Consequently, real production of trout per 1 ha of waters would amount to 20 kg/ha. Taking into account the fact that, for instance, in Poland there are lakes which give natural production of eel of over 20 kg/ha (not to mention other fish species) at no greater expenses, or over 40 kg/ha of coregonids, the efficiency of utilization of land (or water) area for the production of predatory species seems rather questionable.

This example may seem dubious because at present animal protein components in trout feed are very rarely, if ever, taken from freshwater bodies where area calculations are of importance. Nevertheless, in view of the increasingly world-wide lack of proteins it is quite certain that marine fisheries will also face the problem of most effective utilization of marine fish resources. It is questionable whether it is economic to pass proteins through animals with high losses in order to produce protein again. It is of course possible to substitute animal protein with plant protein (to a certain extent) but the same approach must still be adopted as for carp culture.

4.1.2 Efficiency of fish culture expressed in economic indices

The efficiency of fish culture in comparison to other forms of animal production has been discussed, among others, in Polish Case Study No. 4 (1974). In this study the capital coefficient, i.e. the ratio between value of pond construction and level of marketable production in kg, has been used as a measure of the efficiency of fish culture. In order to be able to compare this value with the capital coefficient of terrestrial animal production, it was calculated in relation to the edible part of the product. This study showed that on average the coefficient is twice as high for carp production as for terrestrial animal production (216 and 104 zł/kg respectively), and hence unfavourable for carp production. However, further studies (enlarged materials) showed that on average this coefficient amounts to about 80 zł/kg in carp production - i.e., it is about 20% lower than in terrestrial animal production. A similar method has been adopted in the analysis of data from 24 Polish carp farms. It was found that in particular fish farms the capital coefficient is about 40% more favourable for carp production than in animal production.

Szamborski (1967) has adopted a different method of analysing the economic effectiveness of investments in fish ponds and in cattle production. He concludes that the indices of efficiency are more or less similar in both cases. The same author, however, emphasized that if other benefits (on a macroscale) of fish culture are introduced in to the calculation such as water retention, anti-fire value, etc., relevant economic indices become much more favourable for fish culture: 17% higher in relation to 1 kg of meat, 16% higher in relation to 1 kg of protein, and 26% higher in relation to the financial value of production than in terrestrial animal production.

The same author points out that the use of materials for building should also be taken into consideration. In the case of fish culture the cost of these materials is very low since production is based mainly on land use. An economic analysis of the efficiency of fish and animal production is in this case highly favourable for fish culture. Proper economic indices, expressed in the cost of buildings, showed that the effectiveness of fish production is much higher compared to cattle production: 45% higher in relation to 1 kg of meat, 44% higher in relation to 1 kg of protein, and 51% higher in relation to the financial value of production.

Worniallo (1976) states that in Polish fish farms, at a production of 300 kg/ha of pond area and with the introduction of the value of other benefits (anti-flood value, or water retention value in areas with water shortage), investments in ponds are more effective than investments in animal production. Murin (1967) made an analysis of the efficiency of a fish combine in the Ukraine and compared it with the efficiency of other types of combines (Table 5).

Table 5

	Type of combine		
	Fish	Vegetable - dairy	Poultry
Net value of production per 1 ha of pond area	637	367	312
Value of fixed capital per employee	20 550	3 095	4 622
Value of production per 1 thousand rubles of fixed capital	339	611	739
Profit per 1 thousand rubles of fixed capital	141	60	93
Profit per 1 ha of producing area	317	33.8	39

The table fully reflects the characteristics of fish culture which give relatively better results per unit area but which also require higher capital investment.

As a result of studies on the economic effectiveness of carp feeding in Czechoslovakia, Vacek (1973) states "... that in the year 1976 the proportion of costs of feeds required to produce 1 kg of protein was three times, 2.6 times and 1.9 times as high than in beef, pork, and chicken meat respectively, as in carp gains". In 1968 this cost was 2.6 times, 2.5 times, and 1.8 times as high as in carp gains.

Shang (1973) undertook comparative studies on the efficiency of aquaculture in Taiwan. He stated that: "... from a protein nutrition point of view it is cheaper to grow some aquatic rather than land animals in Taiwan. The rate of return on investments is higher in aquaculture than in ocean fishing and pig farming". It is also possible to compare brackish water culture (mainly milkfish) and freshwater culture (carp and tilapia) with hog raising. The following average indices of productivity and production costs per 1 ha are obtained (Table 6).

Table 6

Type of husbandry	kg/man-year	kg/ha	Cost/kg in US\$
Fresh water	10 453	1 537	0.31
Brackish water	5 098	2 112	0.37
Hog raising	12 000	-	0.43

After Shang (1973)

The high efficiency of aquaculture, especially of freshwater Fish culture, is quite obvious. It becomes even more pronounced by analysing the productivity of labour and cost of production per unit of protein. The average values of these indices are presented after Shang (1973) in Table 7.

Table 7

Type of husbandry	kg protein/man-year	cost/kg in US\$
Fresh water	1 148	2.80
Brackish water	519	3.63
hog raising	757	6.81

Special attention should be given to the disproportionately lower costs of protein in freshwater fish culture, constituting 77% of brackish water culture and 41% of hog production. Shang (1973) also stressed the great effectiveness of investments in aquaculture compared with various forms of ocean fisheries.

Significantly lower labour requirements of fish culture compared with animal production were pointed out by Babaian and Gordon (1968). According to these authors, pond production of carp is less labour intensive than cattle production, and constitutes 42.9% of the latter in relation to live weight, 32.6% in relation to edible parts, and 38.9% in relation to proteins.

Shang's (1973) data as well as many other data prove that, intensification of production generally affects the economic efficiency of fish culture positively compared to other forms of animal production.

The efficiency of polyculture is also higher than that of animal production, since - as a rule - polyculture is more effective than monoculture. According to Bardach (1978) polyculture is about twice as energy efficient as monoculture, both of the relatively cheapest non-aquatic stock (chicken) and of the relatively cheap aquatic monocultural stock (catfish). Calorific input per 1 g of protein production for catfish monoculture in the USA is 139 calories, broiler chickens in the USA is 149 calories per 1 g, and polyculture fish in Israel is 65 calories per 1 g. The levels of technology are roughly comparable, and the energy prices of technological inputs are more expensive in Israel than in the USA.

As regards the farming of predatory fish species, especially trout, it is difficult to make any definite statements. Nevertheless, since in practice trout culture constitutes a luxury food industry (Weatherly and Cogger, 1977), and hence market prices of its product are rather high, at least some economic indices of trout culture efficiency might be favourable when compared with indices for animal production.

It should also be remembered, that assessments of the efficiency of fish culture versus other forms of animal production generally fail to take into account the fact that (with the exception of highly intensive industrial fish culture) other forms of fish production are ecologically clean, whereas animal production is always connected with negative effects upon the natural environment. Unfortunately, no such problems are covered by traditional methods of economic analysis. Similarly, there is no place in such analyses for non-productive values, which are quite significant in the case of fish culture, especially in ponds.

References

See references numbered 8, 10, 37, 49, 74, 77, 79, 89, 90, 106, 119, 125, 129, 131, 135, 148, 152, 158, 159, 165, 180, 183, 194, 197.

5. SPECIFIC ROLE OF FISH CULTURE

5.1 Specific Role of Fish Culture as a Producer of Animal Protein, Source of Income, Employment, and Activity on a Local Scale

On a local scale in particular regions and countries, fish culture often represents if not the main, then at least a fairly important producer of animal protein. Its promotion and development on a larger scale are usually connected with the stimulation of the given region, increase of employment, creation of a new source of income, encouraging this activity by means of a feed-back mechanism.

Ananiadis (1977) has stated these facts in a discussion of the prospects of fish farming in Greece, concluding that: "... The development of aquaculture in Greece can provide good economic benefits and secure an additional source of protein for the low income agricultural sectors of the country. But the main advantages of this activity will be in the provision of work and its contribution to an improvement in the rural economy. It will offer a new source of income derived from a first class product in the national and international market, with obvious benefits both to the rural population and to the country as a whole".

This specific role of fish culture is increasingly appreciated. As is stated in a report from the FAO's First Regional Workshop on Aquaculture: "... in recent years many of the governments in Africa have recognized the important role that fish farming can play in rural development and as a source of supply of nutritious food" (Cedric Day, 1977).

Taiwan constitutes a good example of the local significance of fish culture. As stated by Shang (1973) "... At present, pond raised fish contribute much to family nutrition in Taiwan. Aquaculture accounted for about 22% of total fishery production in 1970 ... Based on a consumer survey of 1 000 families, 592 families indicated that milkfish is the most frequently purchased fish". The author points out that in Taiwan fish is the cheapest source of protein. The amount of protein that can be purchased for the same price is in the case of fish 45%, 58%, 47% and 32% higher than in the case of meat, poultry, eggs, and vegetables respectively (Shang 1973).

Pillay (1973) points to the significant role of aquaculture in employment. He states that in Korea aquaculture employs 130 thousand full-time and some 300 thousand part-time workers, in the Philippines over 170 thousand people and in Indonesia over half a million.

Barting (1973) points out that in the Federal Republic of Germany "... professional pond farming and fish hatching comprises about 5 200 enterprises, of which 4 300 are engaged in carp pond farming and 1 465 in trout hatching. In nearly 340 enterprises the proprietor earns his living mostly with fishing (full-time job)". In 1974 pond farming in this country yielded production to the value of over 64 million DM.

Such examples of the role of fish culture are almost infinite and many refer to fish culture in a region of intermediate geographic scale. They do not, however, take into account the level of the individual fish farm. The great importance of doing so has been stressed by a Regional Workshop of Aquaculture Planning in Asia (Bangkok, 1975). It was stated that "... in countries like Thailand it has been shown that the average income of the fish farmer is about 6 times more than that of an agricultural farmer and substantially higher than that of a coastal small-scale fisherman" (regional Workshop....., 1975).

The high economic efficiency of fish culture constitutes a factor which strongly stimulates its development even when practised as a by-product, in most cases connected with agriculture. According to Martyshev (1970) many collective agricultural farms in the Soviet Union also organize fish farms, treated as a specific by-product. Sometimes the results of these farms exceed all expectations, so that in many instances the role of fish culture becomes dominant from an economic point of view. The author gives an example of a farm in which introduction of fish production created a rather peculiar situation - animal production of the collective farm gave only 40% of the total net income obtained from fish production, although

in the first form of production 450 workers were engaged, while the second form, only 12. According to this author numerous fish farms within collective and state agricultural farms give higher production than farms specializing in pig production. Generally, fish culture in agricultural farms constitutes a source of considerable income.

Luchenko (1971) points to the broad prospects for developing fish culture within the context of agricultural farms. He underlines the fact that the high profitability of fish culture in agricultural farms is usually connected with the possibility of disposing of large supplies of fish feeds in the form of cereal waste products and the possibility of using the ponds for a variety of purposes.

Chuprov (1975) states that in 1973 collective farms in the Soviet Federation have undertaken fish culture which is highly profitable (rentability amounts to 40%). According to this author, 2% of people employed in fish culture have yielded 7% of commercial production and over 12% of total farm income.

References

See references numbered 4, 12, 22, 27, 41 bis, 91, 94, 117, 131.

5.2 Role of Fish Culture in Changing Negative Goods into Positive Goods, and Especially in Maintaining the Quality of Waters

Fish culture frequently utilizes sewage and waste waters for production of animal protein. In this respect it is practically the only form of animal production which can and does directly change so-called "negative" goods (Jermakowicz, 1976) into "positive" goods.

Allen and Hephner (1976), Pillay (1973) and numerous other authors underline this value of fish culture. Allen and Hephner (1976) have even made a comprehensive analysis of benefits resulting from the utilization of wastes by fish culture. These benefits were divided into two general categories: "... those related to fish culture, and those related to wastewater treatment".

Although this role of fish culture is extremely important, literature on the subject does not really present any satisfactory economic analyses that would define the resulting total costs and benefits. To a certain extent this fact is understandable since utilization of waste-water in fish culture is often characterized by extremely high production, so that the economic side of the problem is usually omitted from the discussion. Furthermore, so far it has been rather difficult to incorporate non-measurable benefits resulting from such fish culture into economic analyses.

From the point of view of premises involved in the promotion and development of fish culture, the lack of an economic is highly unsatisfactory. In many cases economic calculation that would take into account this role of fish culture, might completely change its apparently low efficiency of production compared to other forms of producing such goods.

At present it is becoming increasingly necessary to work out a method of economic analysis which would incorporate these values. These benefits might, for instance be measured by calculating the cost of fertilizers saved, although even in this case the value obtained will be underestimated since beneficial environmental effects are not taken into account. It should also be added here that such culture operations are restricted in location because the transportation of wastes might otherwise decrease the net benefits.

References

See references numbered 1, 59, 117.

5.3 Utilization of Waste Lands and Barren Waters by Fish Culture

Reclamation of waste lands, and restoration of barren, unproductive waters, by fish culture are becoming more and more widespread. Europe, (at least in some parts), is quite rich in unused bog lands, i.e., areas remaining after the disappearance of water bodies.

Liszkowski (1978) has made an effort to adapt two such areas in Poland (one of 30 ha, and another of 70 ha) for fish culture. The effects of a 2-year fishery management of these water bodies are presented in Table 8.

Table 8

Area of the water body in ha	Feeds kg/ha	Fertilizers NPK/ha	Fish catch kg/ha	Weight increment kg/ha	kg of feeds per kg of	
					Fish catch	Weight increment
30	1 639	80	904	731	1.8	2.2
70	1 348	38	743	446	1.8	3.0

Ananiadis (1977) draws attention to the possibilities of promoting fish culture in areas unsuitable for agriculture in Greece. He states that "... over 9 000 ha of saline or alkaline uncultivable soils are suitable for aquaculture", and estimates that in such areas production of carp might reach 2.8-3.0 t/ha with feeding and fertilization. He also states that other forms of aquaculture could be similarly developed in swamps.

According to the Bureau of Fisheries and Aquatic Resources (1977), over 500 000 ha of swamp land in the Philippines, which represent virtual waste lands giving negligible profits from forest products, could be used for fish production in ponds. This information does not contain any estimation of the expected results, but it underlines that, in 176 000 ha of pond situated in similar areas production reaches over 600 kg/ha of fish and other products and hence should be economically feasible. The December 1977 issue of Fish Farming International presents some interesting information on the utilization of a desert oasis in Jordan for fish culture. It is anticipated that fish production will reach 3 t/ha, and the farm area will cover 50 ha.

In India, too, there are several possibilities for developing fish culture in swamps and small ponds (Anon., 1977a). However, this statement must be treated very carefully since the costs of turning the swamps into ponds as well as their ecological role must be taken into account.

Possibilities for utilizing waste lands and water bodies for fish culture have never been the subject of even preliminary economic analysis. In view of the possibilities for promoting fish culture in areas suitable for this purpose alone, (Pillay, 1973) it would be necessary to know for instance, to what extent possibly higher costs of fish culture activities in such areas may be compensated by the low cost of land. It is clear that there is a great need for economic analyses of this type.

References

See references numbered 4, 88, 116, 117, 185, 186.

5.4 Other Specific Roles of Fish Culture

Although the three basic specific roles of fish culture discussed in Part I, sections 5.1, 5.2, and 5.3 are commonly known, accepted, and acknowledged, they are never properly taken into account in the appraisal of the economic efficiency of fish culture. Apart from these three basic ones, fish culture frequently plays several other specific roles, which are usually not even recognized or included in economic assessments of fish culture and no attempts are being made to introduce them in any form into such assessments.

Literature on the subject gives only sporadic and incomplete information. However, due to the fact that these aspects of fish culture can in certain situations, play an important part in the assessment of its economic efficiency, I shall specify here at least some of the most important ones:

role of fish culture as a factor decreasing the cost of exploitation of investments in water resource management;

role of fish culture in the development of commercial and recreational fisheries;

role of fish culture in the development of recreation connected with water environment;

role of fish culture in creating water reservoirs and hydrological devices.

6. INTENSITY OF FISH CULTURE AND ITS MEASURES

Definition of the level of fish culture intensity constitutes an important element in the assessment of different forms of fish culture, especially as regards the economic and technical efficiency of fish farming. It provides possibilities of comparisons between different forms and different stages of fish culture development. Moreover, proper definition of the level of intensity can become a significant prerequisite, indicating not only the possibilities for further development and intensification of fish culture, but also the optimal ways and methods for such development. In view of this it becomes essential to find some criteria distinguishing intensive and extensive fish culture, particularly since both terms are quite common. Unfortunately, although these terms are widely used, their meaning is usually explained by a variety of indices and measures, so that the whole problem remains rather difficult.

Eleonskii (1946) distinguished three types of pond farms, depending on the intensity of fish production;

extensive farms, in which production is based exclusively on natural food resources of ponds, i.e., on so-called natural productivity;

semi-intensive farms, in which partial pond fertilization or periodic supplementary feeding is undertaken;

intensive farms, in which production of fishes is based on systematic fish feeding, or complex pond fertilization, or both.

Martyshev (1973) in the same way as Eleonskii (1946) distinguished three levels of intensity, but his definitions are much broader. He also states that extensive forms of fish farming consist of utilizing exclusively natural food resources, but at the same time he points to the relativity of the term. According to this author, extensive fish culture in fact comprises some important intensifying elements. He mentions, among others, the construction of ponds adapted to the requirements of particular age classes of fish, the farming process in itself - beginning with eggs and ending with market fish, selection of spawners, improvement of fish species through selection, improvement of ponds, etc. Nevertheless, apart from these measures, fish yield in this form of culture is significantly limited, and its improvement can be achieved mainly by increasing the area of production.

The semi-intensive form is defined by this author lying between extensive and intensive, being connected with periodic supplementary feeding and partial fertilization of ponds. Fish stock in ponds can be increased according to the amount of feeds or fertilizers used. The author underlines the fact that both measures are aimed not only at increasing the fish stock, but also at increasing the individual weight of fishes.

The intensive form consists of systematic fish feeding, fertilization of ponds, and complex intensification (i.e. the sum of all possible inputs increasing fish production). The author states that as a result of all these measures, undertaken jointly or separately, fish yield per unit area is many times higher than in the extensive form.

Sokhovierkhov and Sivercov (1975) also distinguished three levels of intensity of fish culture, but they changed both the content and scope of the three terms. According to these authors extensive fish culture consists entirely of utilizing natural food resources for the culture of carp age classes, together with other fish species in the same water body. This form of fish culture may be undertaken in reservoirs used for other purposes, such as reservoirs of drinking water, or in large water bodies in which feeding is pointless. The semi-intensive system consists of utilizing natural food resources in fertilized ponds and of increasing the stock of carp bred with other fish species. Supplementary feeding may be applied in the second half of the season, and its consists of cereal waste products. The authors point out that this system is most appropriate for covering local demands for fish in agricultural areas specializing in grain production, far away from larger industrial agglomerations. The intensive (or fattening) system is defined by these authors as carp or other fish farming based on artificial feeding with balanced feeds. Such a system also requires the high natural productivity of ponds which is obtained by fertilization.

According to Wieniawski (1965) extensive carp culture in ponds is based mainly on utilization of natural food resources, and intensive on supplementary feeding along with increased stocking rate. The author, however, does not limit himself only to these two levels of intensity and states that "... level of production intensity can be different and depends on the ratio between fish yield obtained on natural food and fish yield obtained on artificial feeding".

Huet (1971) distinguished different levels of fish culture intensity stating that extensive or semi-intensive farms are those "... in which natural productivity is more or less preponderantly important (in carp culture for example). When farming is intensive (trout and eels for consumption) production rests entirely on feeding and can be very high. The roles of natural food and fertilization, as well as that of the resulting productivity, are non-existent or negligible". As regards carp farming the same author states that: "... there is extensive rearing without artificial food being distributed, there is semi-intensive in which only a small quantity of artificial food is distributed, and there is intensive raising in which an abundance of artificial food is distributed (mostly vegetable cereals and legumes). Ponds can be fertilized or not". Huet regards these three levels as traditional ones, distinguishing for cyprinids another level of production intensity, i.e. "... intensive condensed rearing" for "... the production of fattened cyprinids under intensive and condensed conditions (maximum of fish in a minimum of water)". It is worth pointing out that the latter author introduced level of production as a measure of the level of intensity. This is even more obvious in the chapter on trout culture. The author states there that "... extensive method is based on the consumption of natural food raised in ponds" in which "... production of trout can reach 100 kg/ha in average ponds, and 200 kg/ha in good ponds".

Level of production, or the fish yield, is rather frequently used as the criterion for estimating the level of fish culture intensity. This is illustrated by Tal (1974). He states that "... we are now having three levels of production: 1. the conventional system with yield 4 t/ha per annum, 2. the semi-intensive with 10 t/ha per annum, 3. the intensive method with 20 t/ha or more per annum".

Fish yield is so frequently taken to be synonymous with fish culture intensity that it is not possible to cite the references here.

An especially valuable approach, introducing economic thinking into the evaluation of the intensity of fish culture, was adopted by Hickling (1962). He states that "... fish culture may be extensive, or intensive, or any point between the two. In extensive fish culture a larger area of pond is used, or a suitable piece of water may be stocked, fertilizer may be used, and the entrepreneur is satisfied with a moderate yield of fish got at low recurrent cost ... In semi-intensive fish culture the crop of fish is increased partly or mainly by the use of fertilizer, but partly by supplementary feeding. This entails higher labour costs, and the cost purchasing the feed, but the higher crops more then compensate for this In intensive fish culture, the ponds tend to be small, and are stocked with fish to the maximum, and fish are heavily fed with supplementary food. In such cases natural food produced in the ponds plays a subordinate role, and the growth of the fish is almost wholly at the expense of supplementary food, and in proportion to it The best known intensive fisheries are the trout farms, which produce high price fish at a very high rate of production per unit of water area. Both labour costs and the costs of suitable food for the fish are high, but the value of the product bears this".

Working definitions given by Rabanal and Shang (1976) also go along these lines:

"... Extensive culture - one which utilizes only traditional techniques (such as dependence upon natural productivity of the water and a little control over stocks) usually resulting in low production.

Intensive culture - one which utilizes improved techniques (including scientific pond-design, fertilization, supplemental feeding, stock manipulation) resulting in high production".

It is worth stressing that these definitions imply a rather arbitrary assessment of the intensity of fish culture. In reality, however, the authors distinguish the two essential methods of fish culture on the basis of several different indices, either production (such as annual stocking rate, annual yield in kg/ha), or economic (percentage share of particular major items of operating costs, rate of return on investment, cost of production per kg of fish etc.), with a special role being ascribed to feeding and fertilization.

Definitions of the level of fish culture intensity in which an economic approach is coupled with a production one, are those proposed by Leopold (1976):

"... Extensive system of fish farming - farming of fish characterized by relatively low input costs, giving as a rule low fish production and benefits.

Intensive system of fish farming - farming of fish characterized by relatively high costs of applied means and measures, giving as a rule high fish production and high economic effects".

It seems that the value of these definitions lies in the integration of economic and production approaches, while their shortcomings are their abstract general nature.

An opposite approach has been adopted by Neal (1973). Extensive aquaculture is defined as: "... raising fish or shell-fish in natural bodies of water with few or no modifications of the environment", whereas intensive aquaculture as "... rearing animals in man-made ponds, raceways, or tanks, where considerable environmental control is exercised". The latter author discusses the various legal, biological, economic, environmental and social implications of these two basic forms of the aquaculture, but his final general conclusions boil down to the strictly economic level, and the criterion for undertaking one of the two forms is assessed by its profitability.

Webber (1971, 1975) adopted a similar, although more precise, approach. This author compared land animal breeding with water animal breeding. Apart from obvious differences between the two, he distinguishes five different levels of the intensity:

- ranch management of aquatic animals;
- static pond or pool aquafarming;
- raceway culture;
- cage or basket culture;
- closed high density culture system.

Features distinguishing these levels are based on the development of production techniques, and can be defined according to the degree of regulation or control exercised over the given form of aquaculture. Each form is briefly discussed and its environmental, management and economic implications are stressed.

The value of this approach lies in a clear definition of each level of the intensity of aquaculture. In practice each form distinguished by the author can be very different with respect to the level of intensity, depending, for example, on the level of costs (inputs). Ranges of costs, and hence the results, will overlap independently of the development of production techniques. Consequently, the criterion used by the author has only theoretical value.

All these attempts at defining the level of the intensity of fish culture clearly show that there are still no absolute criteria for separating extensive forms of aquaculture from intensive ones. The problem becomes even more complicated when we try to use various indices adopted for the assessment of fish culture intensity. In practice there are numerous such indices used, but the most common are:

- level of fish yield per unit of area or volume of the given unit of fish culture (pond, tank, cage, etc.);
- ratio between the stock and the yield that could be obtained exclusively on the basis of natural productivity;
- stocking rate;
- level of production (in kg) per employee;
- operating costs of their selected items, especially feeding;
- level of investment per 1 kg of fish.

Each of these indices can be useful for a relative assessment of the intensity of fish culture in a particular situation, but none of them has universal application especially if isolated from the others.

A better solution would be to base the assessment of fish culture intensity upon a properly selected set of different indices. So far however such selections have been arbitrary and accidental. In reality all indices used in assessing the intensity of fish culture can be divided into two basic categories:

- those that can be treated as "costs" from an economic point of view; and reveal little or nothing about the effects (results);

- those that can be treated as effects (results), and in a similar way do not reflect the costs.

In order to make the assessment of fish culture intensity useful for evaluating the economic efficiency of fish culture, it is necessary to possess a set of indices made up of a small number of items best reflecting both costs and results. On the other hand, in order to make such an assessment universal, i.e., applicable to a variety of conditions and situations, it must comprise basic items of costs.

Thus it seems that the best (although not fully satisfactory) indices of the intensity of fish culture would be the cost of input calculated per unit of production, per unit of production area and/or volume, with special attention being paid to capital, energy, material, labour, and land requirements. Any assessment of the intensity of fish culture should include at least some of the above elements of cost items, due to the following reasons;

- these elements constitute an indispensable component of each economic evaluation of fish culture as such;

- they point to the factors limiting or stimulating the development of fish culture;

- they provide a basis for alternative solutions with respect to the intensification of fish culture due to the fact that they may be able to substitute for each other;

- they create a basis for better comparisons between different forms of fish culture, to a large extent independently of the differentiation of fish culture.

A somewhat similar approach has been adopted in an extremely interesting attempt to classify different fish farming systems, made by Edwardson (1976). Its starting point consists of generally understood resource requirements. Assuming that all production inputs except land and labour resources can be expressed in energy requirements, the author makes an analysis of fish farming systems taking into account only three types of resources. These are: gross energy requirements (GER, in GJ/t), farm land area (in ha/t), and manpower (in man-d/t). Based on the analysis of 37 fish farming systems in various parts of the world, the author arrives at the following classification of fish farming systems as regards their intensity (Table 9):

Table 9

Level of intensity	Resources		
	GJ/t	ha/t	man-d/t
Extensive	< 1	> 1	> 120
Low intensity	1 - 10	0.5 - 1	90 - 120
Medium intensity	10 - 50	0.1 - 0.5	50 - 90
High intensity	50 - 100	0.01 - 0.1	25 - 50
Very intensive	>100	< 0.01	< 25

Although the author himself does not discuss the intensity of fish culture, but rather the classification of fish farming systems by resource requirements, it must be pointed out that in view of the above the result is the same. In reality we are dealing here with a definition of different levels of fish culture intensity, based on broadly understood energy requirements (i.e., comprising also capital and material requirements), labour requirements and land requirements.

In practice, it would be very difficult to calculate precisely the GER. Nevertheless, this approach is of great value, mostly due to the fact that the assessment of the intensity of fish culture is based here on an integrated analysis of farm land requirements (ha/t), and man-power requirements (man-d/t). These two values in practice are either similar, close to, or comparable with a variety of the most common indices used for assessing the intensity of fish culture, such as:

- catch in kg per unit area;
- catch in kg per fisherman;
- number of employees per unit area;
- farm area per fisherman;
- man-hours per unit area, etc.

When properly interpreted, these values can also serve for evaluating the efficiency of fish culture. In most cases it is quite easy to obtain the basic data for calculating these indices, or even the indices themselves. Some of them, taken separately or in proper combinations, have already been used by the Working Party, as well as in papers presented at the FAO Technical Conference on Aquaculture, held in Kyoto in 1976, e.g., the review by Rabanal and Shang (1976).

The latter paper, although most valuable from several viewpoints, constitutes a typical example of how deceptive it might be to use only strictly economic indices for an assessment of the intensity of fish culture. This statement is especially true if such indices are used for comparisons, not only on an international, but also on a national scale. In most cases the structure of operating costs, and hence of derived economic indices, does not result from the given level of intensity, but rather from general conditions of fish culture, or even from the methods of accounting, which are always based on some simplifications and assumptions. This statement can be illustrated by several examples.

Example 1: In many cases different methods classifying cost grouping for the purpose of cost accounting render very difficult, or even make totally impossible, any precise definition of the intensity of fish culture, as well as the assessment of its economic efficiency solely on the basis of economic indices. It was assumed (EIFAC 71/Circ. 2) that two groups of costs should be distinguished in order to be able to undertake proper studies on the economics of fish culture namely:

- A. Capital investment, and
- B. Operating costs.

However, as is seen from the paper by Rabanal and Shang (1976), even this general division cannot be made in all cases, so that instead of group A (capital investment) - we have:

construction costs;
fixed capital;
fixed costs.

The problem is further on complicated by the fact that this group also frequently comprises cost items which in other cases are included under group B (operating costs) such as equipment for instance. In the paper by Rabanal and Shang (1976) in Tables III to IV equipment is listed under group B (operating costs), while in most other tables - under group A (capital investment) e.g., Tables V to VIII, and X to XII.

The division into fixed cost and variable cost (Table XVII of the same paper) is even more complicated. This type of cost grouping is totally different from the division into capital investments and operating costs.

Example 2: It is dangerous to use economic indices if there is any uncertainty about whether a common base is being used for comparisons. In many cases several items of costs are omitted, and their lack or presence or absence is not connected with the intensity of fish culture. Most typical examples of such cost elements are value of land, value of buildings, marketing cost, or cost of water, all of which are frequently quite considerable. To exemplify the point, let us consider the comparison of cost and return from milkfish culture in the Philippines and in Indonesia, made by Rabanal and Shang (1976), Tables I to IV, and V to VII. In the first case, cost of marketing, amounting to the significant level of 11% of total revenue, is covered by the producer, while in the second case (Indonesia) - by the buyers. In most cases however,, this item is not imputed at all.

The same applies to water. In Table VIII of the same paper cost of water represents 23% of all costs (fish culture without feeding), but in most cases this item is omitted.

Example 3: Several assumptions are made in many cases of cost accounting, e.g., the Polish cost data on stocking material produced by the farm for its own use, are not included in the cost accounts. However, this cost is entered in the books if stocking material is bought from other fish farms. Hence the structure of operating costs cannot be compared here as has been already pointed out by Labon (1972).

Another specific assumption is made when the same level of construction costs is taken independently of whether we are dealing with mono or poly-culture (or intensive and extensive fish culture). In view of the relationships existing between the level of production and investment costs, in which pond construction constitutes the main item, such an approach would seem oversimplified.

Even these few examples point out that each type of economic assessment of fish culture and its intensity, cannot be based solely on strict economic indices, but rather on indices which are independent of the method and characteristics of economic accounting. Such indices would certainly embrace some natural indices (as discussed before), production indices, indices of resource requirements with special attention being paid to the most readily available ones, i.e., to labour requirements, land requirements and material requirements mainly feed, fertilizer, and stocking). In reality these indices or their derivatives are also used independently of the economic indices by Rabanal and Shang (1976) in their paper.

Including resource requirements (measured in physical units) as an integral part of economic accounting constitutes the first step of conversion from classical cost accounting or investment appraisal to the cost benefit analysis necessary for any reliable overall appraisal of different forms of fish culture.

References

See references numbered 39, 40, 54, 56, 86, 95, 110, 121, 146, 166, 167, 170, 191, 197.

PART II - ECONOMIC ANALYSIS OF FISH CULTURE

1. FACTORS AFFECTING THE ECONOMICS OF FISH CULTURE

1.1 Size of Ponds, Pond Complexes, Pond Farms, and Other Units of Fish Culture

The size of ponds, and also of pond complexes and pond farms, constitutes one of the most significant factors in determining the economics of fish culture, especially of pond fish culture. The same is also true of other production units for fish culture. The size of units used for the fish production can be treated as a specific economic factor, since it usually has economic implications. The effect of this factor may either be direct, e.g., resulting for the scale of production, or indirect - resulting from various production and biological consequences of the size of the production unit.

1.1.1 Size of ponds

The optimal size of ponds has never been clearly defined, and many authors often have different views on the matter. The only common point acknowledged is that in most cases the optimal size of ponds is defined from a single and too narrow point of view. This applies especially to ponds for farming of commercial fish, since there is broadly general agreement that ponds used for rearing stocking material should be rather small.

The problem is discussed most frequently as regards carp farming, due to the present scale of carp culture in the world, especially Europe, and also the prospects of its further development. Furthermore, the size of ponds, pond complexes, etc., is frequently quite comparable, which is significant in relation to the economic appraisal of different forms of fish culture.

Wienawski (1965) states that "... the size of ponds is not particularly important, usually being limited only by the technology and organization of fish culture. Similarly, shape of ponds does not have any decisive effect - although a well developed shore line can be a positive factor. Both the shape and the size of carp ponds are usually adapted to the situation and land configuration, in order to minimize the earth works".

The author clearly contradicts himself since on the one hand he states that the size of ponds is not significant, but on the other, he underlines its dependence on the technology and organization of fish culture, also stressing the effect of shore line (a function of size). Furthermore, he also takes into account the earthworks, which are very significant from an economic point of view.

Eleonskii (1946) states that commercial carp ponds are usually the largest but that they should not exceed 50-100 ha since smaller ponds allow more thorough control. Gnatiuk and Sigal (1973) state that in the opinion of the fishermen, ponds larger than 100 ha are not effective due to the fact that they give increased fish losses, and are characterized by a shorter life.

Donskii (1974) discusses the superior results of a 3-year carp production cycle compared to a 2-year cycle in a Belorussian farm which utilizes a water purification system for carp farming. He states that high production results were achieved in ponds with an average surface of about 200 ha but that the recommended size of ponds in specialized farms should be 100 ha. According to Sukhoverkhov and Sivercov (1975) the present state of knowledge restricts the size of commercial ponds to no more than 100 ha. In Czechoslovakia the highest economic efficiency was ascertained in the group of ponds between 20 and 50 ha (Vacek, 1969).

Khristian and Grobokopatel (1975) point to the fact that high fish production is usually achieved in ponds not exceeding 150 ha and that ponds bigger than 200 ha are usually characterized by low production. They are of the opinion that low production of bigger ponds is determined by the poorer quality of such ponds, as in most cases they are undrainable.

Furthermore, large size increases the labour requirements of normal farming operations, such as feeding. According to these authors, production of large ponds could be increased by mechanization of most labour-consuming production operations, and by improving the environmental conditions in such ponds. It should be noted that in many cases lower production of large ponds is more connected with relatively poor environmental conditions in such ponds than with their size. The same opinion is expressed by Murich and Grobokopatel (1968) in the analysis of basic factors affecting fish production of commercial carp ponds in the Ukraine. They separated the effect of pond drying and the effect of pond size while the latter was treated as an objective factor, affecting the production totally by itself. However, if we arrange in one table the figures presented by these authors in two tables, we obtain the following picture (Table 10):

Table 10

Group of farms with production of (kg/ha)	in this % of ponds			
	drainable	undrainable	up to 100 ha	above 100 ha
up to 200	15.3	84.7	32.4	67.6
200 - 400	60.3	39.7	42.1	59.7
400 - 800	84.9	15.1	82.4	17.6
over 800	94.9	5.1	87.2	12.3

It is obvious from this table that the apparently negative effect of pond size on fish production can be a spurious correlation, resulting from the fact that big ponds are usually undrainable, as opposed to small ones. It is obvious that ponds which cannot be dried will have lower production.

The above statement does not, of course, negate the effect of pond size, but there are also other important biological and production premises pointing to the fact that big ponds are relatively less productive than small ones. According to Shpet (1961) this is determined by:

(a) Unsatisfactory ratio of shore line to area - obviously the shore line of one big pond is shorter than of several small ponds of the same area. The shore line defines the littoral zone of a pond, which - he claims - is the most productive zone of a pond. Higher temperature and better insolation result in the food resources of this zone being much higher than in the central part of ponds.

(b) Greater depth of larger ponds, unfavourable for the growth and feeding activity of fishes. This is connected with lower temperature, lack of aquatic plants, and oxygen deficits in the bottom layer. The author states that aquatic plants are very important for the productivity of ponds. In large ponds their development is restricted by depth and the growing season is shortened. Under Ukrainian conditions the growing season of aquatic plants in large ponds is over 1 month shorter than in small ponds. The author explains this phenomenon by wave and wind action, being stronger in large ponds.

(c) Specific microclimate connected with water areas, characterized by frequent strong winds resulting in increased wave action - this, in turn results in an increased amount of suspended matter in the water, and in sedimentation of larger particles in the deepest parts of the pond. Consequently, large ponds possess unproductive sand zones in their shallower parts.

(a) Limited number of places suitable for fish feeding in relation to the size of ponds - usually no feeds are distributed in the central, deeper part of the pond.

(b) Difficulties in exercising effective control of weed and predatory fishes - these are quite common in large undrainable ponds and as a result the efficiency of fish farming decreases. Effective control of fish diseases is also very difficult in such ponds. Very frequently it is difficult to locate a fishkill or a source of pollution. Many authors state that large ponds are characterized by higher losses compared to small ponds (Shpet, Bakunenko, 1964; Gasiuk, Sigal, 1973), most probably due to the above reasons.

Apart from the above, it is also said (Shpet, Bakunenko, 1964) that large ponds must be dried and fished out much earlier than small ones, hence the growing season is significantly shorter. The same authors point to the fact that although the dikes of big ponds are much shorter (smaller ratio between shore length and pond area), possible savings on the length of dikes frequently do not compensate for the increased costs of dike strengthening and consolidation. The authors significantly go beyond the traditional narrow view, which only takes into account the level of fish production in different ponds, without paying attention to various economic aspects of fish ponds of different size. However such factors frequently determine the efficiency and economics of fish culture, together with the level of production, quite apart from the differences in productivity noted between large and small ponds.

The various economic consequences resulting from fish culture undertaken in ponds of different size can be divided into some general categories:

(i) Problems associated with the level of investments connected with pond construction and other hydraulic devices (e.g., water supply system). Generally speaking there is an inverse relation between the cost of pond construction per unit of area and the size of ponds: the bigger the pond the lower the cost of pond construction per 1 ha. Polish Case Study No. 4 (1974) presents some Soviet data related to this problem (Table 11).

Demchenko and Shpet (1973) state that construction of a 150 ha pond is 20-40% cheaper than construction of a 50 ha pond.

Avault (1974) presents data relating to the effect of pond size on the economics of catfish production based on the results of studies by Foster and Waldrop (1972). Taking 160-acre square tract as a land base, and pond size of 5, 10, 20, 30, 80, and 160 acres, it was found that the decrease in initial investment with increasing pond size was from US\$ 1 730 per acre for the 5-acre pond system to US\$ 947 per acre for a system using one 160-acre pond. "... Most of the economics of the investments associated with size were attributable to pond construction costs". The only item of investment which increased along with increasing pond size were those associated with fish harvest.

Table 11

Area of pond in ha	Cost of pond construction per 1 ha in %
2 - 20	100
20 - 50	22 - 37
50 - 100	16 - 25
100 and more	6 - 21

The differences in initial investment (mainly pond construction costs) per unit of pond area depending of the size of pond, are above all associated with earthworks, which in turn, are connected with the length of shore line. Since shore line is also affected by the shape of ponds, it is necessary to analyse these physical parameters in this context. Length of the shore line calculated per 1 ha of pond area in ponds of different size and shape is presented in Table 12.

Table 12

Pond size in ha	Ratio between pond width and length					
	1 : 1	2 : 3	3 : 5	1 : 2	2 : 5	1 : 4
	Shore line m/ha of pond area					
1	400	408	413	424	443	500
5	179	183	185	190	198	224
20	89	91	92	95	99	112
50	57	58	58	60	63	71
100	40	41	41	42	44	50
200	28	29	29	30	31	35

As is seen from Table 12 there are significant differences in the length of the shore line per 1 ha of pond area in different ponds, hence, also the cost of earthworks (for instance dikes construction) is also very different. It may be assumed that these differences are not cancelled out even by the need to construct thicker dikes in larger ponds, so that construction of smaller ponds is always more expensive.

The advantage of constructing larger ponds whenever possible is also supported by another important factor - larger ponds usually have lower land requirements. As Demchenko (1974) found, for the construction of one 150 ha pond, 5% of land is used for building road, dikes and other hydraulic devices, whereas a 50 ha pond requires at least 8% of land for such construction.

Hickling (1962) states that "... the larger the pond the less the cost of construction per productive unit area" but he also points out "... that the most economical size of rearing pond is the largest which can consistently produce marketable fish".

The decision to build larger or smaller ponds is also dependent on the pond site. There are cases when, due to various reasons, it is cheaper to construct several ponds instead of one.

(ii) Problems associated with the remaining investments, and especially with investments aimed at the intensification of production. These investments comprise two groups of costs, those for renovation and maintenance of ponds and pond constructions and those for various pieces of equipment, necessary buildings and means of transport. These investments and their efficiency are for the most part connected with the level of production. Nevertheless, the size of ponds also plays an essential role which is worth a brief analysis.

Generally speaking, the aim of these investments (whether in existing, or in newly established fish farms) is as follows:

- (a) lowering production costs;
- (b) maintaining production at the existing level;
- (c) increasing production.

The constant desire to lower the cost of production is always coupled either with the desire to keep it at an unchanged level (a + b), or to increase it (e + c). In practice two alternative situations related to pond size can occur. Let us assume that we have two ponds - a small one of 10 ha, and a big one of 100 ha.

Situation I. In both ponds total fish production is 60 t. In the small pond this production will result from high yield per unit of area (6 000 kg/ha), while in the large pond - from low yield per unit of area (600 kg/ha).

Situation II., in which the yield per unit area is similar both in a small and in large pond (600 kg/ha), whereas the total fish catch is different.

We have thus four variants and to clarify the situation, let us present them in the form of a table (Table 13).

Table 13

	High yield in kg/ha 6 000	Low yield in kg/ha 600
Small pond - 10 ha	A. High production (60 t)	C. Low production (6 t)
Large pond - 100 ha	B. Very high production (600 t)	D. High production (60 t)

Whether or not a satisfactory investment has been made, very much depends on the point of view, or more strictly on the aim that has to be achieved. Possible allocation of investments in the case of the situations represented in Table 13 (A, B, C, D) is as follows:

In the case of B the main aim would be to lower the cost of production but to keep production at the same level or even possibly increase it. In view of the very high production in this case, it may be worthwhile incurring even major investments.

In the case of A the aims are similar. However, in view of a significantly lower total production, the scope for making major investments will be very limited.

In the case of D the increase of production with a simultaneous lowering of production costs becomes very important. The possible maintenance of production at the same rate would become significant only after production has reached a suitably high level. Similarly (as in case B) there are good opportunities for major investments, but the corresponding risks are much greater.

In the case of C the aims are similar to A, but the possibilities of investments are limited and the risks are high.

In view of the above, small ponds tend always to be in an unfavourable position compared to large ponds, even though they have higher productivity than large ponds.

According to Murin (1965) the size of ponds constitutes the basic factor determining the effective use of various machinery and equipment, since the use of heavy machines necessary for proper renovation of ponds will always be restricted on small ponds due to the high costs of such machinery in relation to the results that can be achieved upon ponds of a small area. The same applies to automatic feeders, aeration, mechanical harvesting, means of transport, etc.

(iii) Problems associated with the intensification of production in ponds of different size. Many authors, as for instance Eleonskii (1946), or Demchenko and Shpet (1973), suggest that higher production in small ponds does not solely result from their size but also from the fact that it is easier to intensify the production in such ponds. This opinion is indirectly supported by studies undertaken by Demchenko and Shpet (1977), dealing with the yield of Ukrainian ponds in the past 20 years. Based on these studies it may be concluded that, independent of the general increase of fish yield in Ukrainian ponds, significant differences exist between small and large ponds. This conclusion is illustrated by Table 14 compiled on the basis of data presented by the two authors:

Table 14

Size of ponds	Average yield in kg/ha		% increase
	in 1951-52	in 1973-74	
up to 100 ha	314.0	1 248.6	397.6
over 100 ha	237.6	843.4	355.1

The difference in the yield of small and large ponds, which in 1951-52 amounted to 30%, was not only still maintained after 20 years, but even increased to almost 50% in 1973-74. This can be explained in two ways:

either lower investments were used for the intensification of large ponds than for small ones,

or large ponds were less susceptible to intensification.

There are no data permitting an unequivocal answer. Nevertheless, any answer clearly points to the fact that size of ponds must be taken into account in economic analysis.

(iv) Problems of production costs in ponds of different sizes. Apart from the increased cost of production due to higher depreciation of capital investment for smaller ponds compared to larger ones, there is another significant factor here, namely different labour requirements. Rabanal and Shang (1976) clearly state that "... the larger the size of fish pond, the smaller amount of labour required per ha of pond". The same conclusion can be found in Moderski and Szamborski (1972) who point to the possibility of obtaining higher labour efficiency on larger ponds.

Demchenko and Shpet (1973), and Demchenko (1974) state that the unit cost of fish production in ponds up to 150 ha is 15-20% lower than in ponds up to 50 ha. Higher labour requirements of small ponds are most clearly visible in the case of pond complexes and fish farms, discussed subsequently.

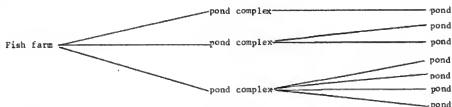
(v) Problems associated with different non-fishery values of small and large ponds. As for all problems associated with non-measurable or intangible values of fish culture, also this problem remains unresolved. Nevertheless, in this context the differences between small and large ponds can be quite significant from an economic viewpoint. Possibilities for the multiple use of larger ponds for various non-fishery purposes, are obvious and need no comment.

References

See references numbered 7, 28, 29, 30, 31, 40, 43, 48, 54, 66, 104, 105, 109, 121, 134, 136, 146, 156, 170, 194, 196.

1.1.2 Size of pond complexes

The relation between ponds, complexes and fish farms is presented in the following diagram:



The number of possible variations can be quite large, from farms with only one pond, through farms consisting of one pond complex with many ponds, to farms consisting of many pond complexes with numerous ponds.

For instance, the total area of 24 Polish fish farms from which data were collected for the Working Party, amounted to 15 516 ha representing 150 pond complexes, i.e., over 6 per farm on average, the range of variations being from 1 to 14 per farm. The average size of pond complexes amounted to 103 ha, varying from a minimum of 33 ha to a maximum of 815 ha. The average size of pond complexes calculated per farm (arithmetical mean for 24 farms) amounted to 163.7 ha.

The structure of one of these farms is presented in Table 15.

Table 15

Pond Complex	Area of ponds in ha	Number of ponds			
		Total	C ₀ -C ₁	C ₁ -C ₂	C ₂ -C ₃
I	11.65	2	2	-	-
II	20.51	2	-	2	-
III	49.29	3	-	2	1
IV	135.17	4	-	3	1
V	190.95	16	13	-	3
VI	256.49	24	-	6	18
Total	664.06	51	15	13	23

As with pond size, the size of pond complexes significantly affects the economics of fish culture and it is unfortunate that neither factor is usually included in economic analysis.

The Working Party had made an initial attempt to draw attention to the problem (Polish Case Study No. 6). In this study pond complex has been defined as "... a group of ponds spatially integrated due to the common water intake, and frequently partly united on an administrative or production basis".

The Case Study presents an analysis of 42 pond complexes (varying from 12 to 191 ha) giving the following results:

There is a negative correlation between the size of pond complexes and the value of capital investments (expressed as the value of pond construction) per unit area. An increase of complex area by 10 ha is connected with an average decrease of the value of capital investment by over 2% in relation to its average level in the sample.

There is a negative correlation between the size of pond complexes and the index of capital intensity (the ratio between the value of capital investment and the value of production). An increase of the complex area by 10 ha results in a decrease of this index by over 6% as compared to its average level for the sample.

Further studies on data from the same 24 Polish farms showed even more clearly the differences of production and economic indices depending on the average size of pond complexes in these farms, as illustrated by Table 16.

The more important conclusions to be drawn are that farms with bigger pond complexes are characterized by the following features compared to farms with smaller pond complexes:

- (i) Significantly better utilization of pond area - 74.3% in farms with bigger complexes and 62.1% in farms with smaller complexes.
- (ii) Higher specialization of production - earnings from secondary production amount to 8.6 and 16.3 respectively.
- (iii) Higher fish yield per unit area both in relation to total farm area and to pond area.
- (iv) Significantly lower labour requirements - respectively 7 535 and 3 439 kg of fish per employee.
- (v) Lower capital investment (45.0 and 63.7 thousand zł/he respectively) and higher rentability 8.0% and 1.1% respectively.
- (vi) Significantly higher rentability of operating costs, amounting to 29.5% and 5.7% respectively.
- (vii) General intensity and efficiency of production, resulting from the above points, as also from the structure of operating costs.

The significance of the size of pond complexes on the economics of fish production is indirectly supported by the studies by Kozun (in prep.). Analysis of production results of 52 Polish fish farms showed a significant positive correlation between the average fish yield/ha and the average size of pond complexes; the higher the average size of pond complexes the bigger the fish yield per unit of area. An increase in the average size of pond complexes by 1 ha is connected with an average increase of fish yield in these farms by 0.325 kg/ha.

Although the latter value may seem rather small, its production, and hence also economic significance can be illustrated by the following example. If we take two fish farms of the same area of 600 ha, in which the average size of pond complexes amount to 100 ha and 200 ha respectively then the difference in the total production of these farms, resulting from this small value alone will amount to:

$$0.325 \times 200 \times 600 - 0.325 \times 100 \times 600 = 19\,500 \text{ kg}$$

It is worth noting that the difference in the average size of pond complexes in fish farms is usually much higher than in the above example.

References

See references numbered 60, 77, 196.

Table 16

	Pond complexes bigger than average		Pond complexes smaller than average	
Number of fish farms	7		17	
Average number of pond complexes per farm	2.9		7.6	
Average farm area in ha	314		577	
Pond area in ha	605		358	
Pond area % of farm area	74.3		62.1	
% of secondary production	8.6		16.3	
Fish yield, kg/ha of farm area	451		304	
Fish yield, kg/ha of pond area	584		460	
Kg of fish per 1 employee	7 535		3 439	
Number of employees per 100 ha	6		8.8	
Capital investments in thousand z1/ha and in %				
Total, which includes:	45.0	100	63.7	100
pond constructions	29.8	66.2	43.0	67.5
buildings	3.1	6.9	6.1	9.6
other buildings	7.0	15.6	10.5	16.5
transport	1.5	3.3	1.8	2.8
others	3.6	8.0	2.3	3.6
Operating costs in thousand z1/ha and in %				
Total, which includes:	12.2	100	12.2	100
stocking material	0.5	4.1	0.2	1.6
fertilization	0.2	1.6	0.4	3.3
feeds	4.5	36.9	3.6	29.5
depreciation	1.6	13.1	2.0	16.4
salaries	3.1	25.4	3.2	26.2
others	2.3	18.9	2.8	23.0
Rentability of capital invest. in %	8.0		1.1	
Rentability of operating costs in %	29.5		5.7	

1.1.3 Size of fish farms

As distinct from pond complexes or individual ponds, the fish farm as a rule represents an individual production and economic unit, which can be subject to proper economic accounting of inputs (costs) and outputs (effects). This constitutes an essential difference between fish farms and pond complexes.

Hence, the effect of the size of fish farms on the economic results of fish farming can be easily analysed, and has been dealt with in numerous papers.

The characteristics of the economics of fish farming in relation to the size of fish farms are presented in Table 17, based on the materials of the Working Party. The table presents data from 24 Polish fish farms in the years 1972-73 and 1973-74. The farms have been divided into small and large in relation to the average size calculated for all 24 farms. Several important conclusions emerge from this table. Large as compared to small farms are characterized by:

- about 28% higher fish production in kg/ha of pond area,
- over 48% higher fish catch per fisherman,
- lower number of employees per 100 ha of fish farm area; in the two years under study by 28.1% and 26.1% respectively,
- lower capital investment per 1 ha of area, by 24.6% and 23.3% respectively,
- lower or similar operating costs. Thus depreciation costs are clearly lower in large farms, as are the costs of salaries and wages, and so-called (other) costs,
- higher rentability of capital investment and operating costs,
- more possibilities for the intensification of production.

This results from the fact that, at the same operating costs, larger farms are characterized by higher production despite worse utilization of the pond area. This is supported by an increase of production noted in both size groups (the same farms in the next year) with respect to the market fish: in large farms this increase (in kg/ha) amounted to over 15%, while in small farms to only about 6%.

Detailed analysis of the materials showed that there is a significant negative correlation between the size of farms and the level of capital investment in thousand z1/ha. The dependence is expressed by the following equations:

$$Y_{1972-73} = 81.36 - 0.0358x$$

$$Y_{1973-74} = 79.66 - 0.0284x$$

where Y - average capital investment in thousand z1/ha, and x - area of fish farm in ha.

Hence on average an increase of farm area by 100 ha decreases the capital investment for the whole farm by 3.58 thousand z1/ha and 2.84 thousand z1/ha respectively in the years analysed. Taking into account that the area of farms under study ranges between 300 and 1 600 ha, the resulting values are enormous. Furthermore, lower investment requirements of larger farms do not have any negative effects, either on productive results or on economic results as proved by Table 17.

Rabanal and Shang (1976) also point to the effect of the size of farms upon their economic results. These authors cite a table by Caradang and Darrah (1973), according to which the cost of milkfish production in the Philippines differs in farms of different size (Table 18).

McCoy and Boutwell (1977) made an analysis of the effect of farm size on the economics of catfish farming. Table 19, based on data given by these authors presents the economics of catfish farming in farms of 80, 160, and 320 acres, calculated with respect to an 80-acre farm. Larger farms are clearly better off economically and this speaks for itself.

The effect of farm size on certain economic indices can be great, as exemplified by an analysis of data concerning the culture of Chinese carp, and Chinese carp with common carp in Malaysia, presented in the Report of Studies on the Economics of Aquaculture in the Indo-Pacific Region. Analysis of farm size and level of capital investment per ha in 39 fish farms proved that there is a highly significant, negative correlation between the two values.

Table 17

	1972-73				1973-74			
	Farms bigger than average		Farms smaller than average		Farms bigger than average		Farms smaller than average	
Average farm area	973.1		450.5		996.6		485.5	
Area of ponds	620.9		316.1		632.3		342.3	
Area of ponds in %	63.8		70.2		63.5		70.5	
% of secondary product.	11.0		15.9		14.1		19.2	
kg/ha of farm area	367.0		335.1		403.9		356.9	
kg/ha of pond area	575.7		447.8		616.8		482.2	
kg/ha market fish	901.3		728.3		1 038.2		769.1	
kg per 1 employee	5 817		3 923		6 127		4 116	
employee per 100 ha	6.4		8.9		6.5		8.8	
Capital investment in thousand z1/ha and in %								
Total	48.4	100	64.2	100	51.1	100	66.6	100
in this: pond constr.	33.8	69.8	42.4	66.0	34.3	67.1	44.4	66.7
buildings	3.7	7.6	6.2	9.7	2.3	4.5	4.9	7.3
other buildings	7.3	15.1	10.8	16.8	9.4	18.4	12.3	18.5
transport	1.4	2.9	1.9	3.0	1.6	3.1	1.8	2.7
others	2.2	4.6	2.9	4.5	3.5	6.9	3.2	4.8
Operating costs in thousand z1/ha and in %								
Total	11.4	100	12.7	100	13.5	100	13.5	100
in this: stock. mat.	0.3	2.6	0.3	2.4	0.6	4.4	0.1	0.7
fertilization	0.4	3.5	0.3	2.4	0.4	3.0	0.4	3.0
feeds	3.8	33.4	3.9	30.7	4.3	31.8	4.2	31.1
depreciation	1.5	13.1	2.1	16.5	1.7	12.6	2.0	14.3
salaries	3.0	26.3	3.3	26.0	3.8	28.2	3.9	28.9
others	2.4	21.1	2.8	22.0	2.7	20.0	2.9	21.5
Rent. cap. invest. %	5.9		1.2		5.5		3.7	
Rent oper. costs %	25.0		5.8		20.6		18.1	

Table 18

Size of farm	Area in ha	Philippine pesos/kg
Small	up to 10	3.89
Medium	10 - 39	2.31
Large	over 40	2.09

Table 19

	Farm area in acres		
	80	160	320
Investment per land acre %	100	87.3	80.7
Investment per water acre %	100	85.8	78.4
Depreciable investment in % of total investment in %	42.0	36.8	33.4
Percentage return on average			
single crop	8.3	17.3	22.2
multiple crop	28.4	39.2	45.0
Net annual return per			
single crop	82.5	154.1	187.3
multiple crop	283.4	348.8	381.7
Total cost in %			
single crop	100	92.1	88.4
multiple crop	100	95.0	92.4

Based on the data by McCoy and Boutwell (1977)

Size of pond fish farms has been analysed by several Soviet authors. Murin (1972) points to the dependence between farm size and the efficiency of production. This author has grouped pond farms of the Ukraine and the Russian Republic according to the level of production. The resulting picture is quite interesting (Table 20).

Table 20

Groups of farms with fish production in tons	Ukraine		Russian Republic	
	Farm size in ha	Fish catch kg/ha	Farm size in ha	Fish catch kg/ha
up to 100	189	269	150	352
100 - 200	365	464	248	610
200 - 400	561	535	412	676
over 400	939	818	835	751

Data for 1970, according to Murin (1972)

Unfortunately, the author did not give any strictly economic indices characterizing the farms, but he stated that in small farms it was not possible to take full advantage of the knowledge of specialists, or of modern equipment.

The effect of farm size is also illustrated by Korobko (1973) and Korolev (1976). Table 21 presents some production and economic indices from the paper by Korolev (1976).

The fact that the economic indices are really influenced more by farm size than by other factors (such as for instance the intensity of production) is proved by Table 22, based on the data given by Korobko (1973). The author points out that he had analysed only those farms which were similar as regards the quality of production basis and the level of intensity. In such a situation the value of overall production in these farms will constitute a function of factors connected mostly with farm size. All values presented in Table 22, with the exception of the rentability of production, are expressed as percentages on a scale in which the group of farms with the lowest overall production represents 100%.

Table 21

Group of farms with overall production in thousand rubles	Average farm size in ha	Fish catch in kg/ha	Profit per 1 ha in rubles	Unit cost of production in %
up to 75	86.0	750	-14.1	100.0
75 - 150	150.1	860	99.0	94.0
151 - 300	268.8	960	136.1	89.6
over 300	485.0	1 100	162.0	88.4

Table 22

Group of farms with overall production in thousand rubles	Cost of Production	Labour requirements in man-days	Profit	Index of the rentability of production
	Per 1 000 rubles of overall production			
Up to 100	100	100	100	14.5
101 - 200	92	80	156	24.7
201 - 300	87	77	189	31.6
over 301	82	63	225	40.0

After Korobko (1973)

The conclusions resulting from Table 22 are clear and do not need any comments. Also two other comparisons, presented by the latter author, point to the direct effect of farm size on its economic results. The author distinguishes the efficiency of market fish and stocking material production. He has furthermore divided the farms according to the level of production. As a result of these divisions the author has obtained different areas of pond for market fish, and for stocking materials and economic indices related to these areas. And thus, for market fish ponds and ponds producing stocking material the relationships are as in Tables 23 and 24 respectively.

Table 23

Area of market fish ponds in the farm(ha)	Index of the rentability of production
70	16.3
110	26.7
370	37.5

Table 24

Area of ponds for stocking material (ha) in the farm	Index of the rentability of production
15	unprofitable
46	17.6
64	60.0
97	71.4

If we take into account the fact that in many cases particular pond complexes of fish farms are specialized either in the production of stocking material or in the production market fish it becomes clear that any economic analysis should take into account not only the effect of farm size, but also the effect of the size of pond complexes or even of particular ponds. There is no doubt that the size of ponds, pond complexes, and fish farms is also a specific economic category, and thus should be treated as a basic common value in economic analysis, or at least its background. In most cases the size of production units, especially in pond fish farming also represents a specific initial element, affecting the results of production.

References

See references numbered 18, 69, 78, 100, 107, 121.

1.2 Depth of Ponds

The effect of pond depth on production results, and thus economic results, has been discussed both in separate papers and together with other problems of fish culture.

Shpet (1961) associates lower productivity of larger ponds with their depth. Stasiniewicz (1970) states that in similar climatic and biological conditions deeper ponds create better possibilities for the intensification of production at significantly lower costs than in the case of shallow ponds. To support this statement the author undertook an analysis of production indices related to 128 commercial ponds of different depth. A summary of his results is presented in Table 25.

Table 25

Stocking material	Pond depth in m	Stocking rate indiv./ha	Feeds kg/ha	Increment kg/ha	Survival rate %	FCR
Fry (C_1)	0.7	1 229	2 515	690	77.9	3.64
	1.2	1 342	2 715	814	77.9	3.33
Yearlings (C_2)	0.7	665	1 940	581	81.0	3.34
	1.2	843	2 595	835	86.2	3.11

Based on Stasiniewicz (1970)

The value of deeper ponds is beyond doubt and does not need any comment. The above results correspond closely with the statement of Glasun and Kharitonova (1975) that the depth of ponds constitutes one of the basic conditions for effective intensification through feeding and fertilization.

Stasiniewicz (1971) also points to the differences of natural pond productivity depending on their depth as illustrated by Table 26.

Table 26

Pond depth in m	Stocking rate individual/ha	Average natural productivity (kg/ha)	Individual weight of harvested fish in g
0.5 - 0.6	1 340	153.7	115
0.7 - 0.8	1 392	247.5	178
1.0 - 1.3	1 714	323.1	188

Based on Stasiniewicz (1971)

Rychlick (1971) carried out an experiment in fish ponds 83-86 cm deep and 113-125 cm deep. Ponds were stocked at the same stocking rate, feeds and fertilizers were used in the same amounts, but the production in the first group amounted to 560 kg/ha, and to 726 kg/ha in the second. Hence, the level of production in deeper ponds was 30% higher than in shallow ones. According to the data given in Table 26, natural productivity in ponds of similar depth, i.e. of 0.7-0.8 and 1-1.3 m is also higher by about 30% in the latter group.

Chizhik and Chumachenko (1976) show that the depth of ponds and the amount of water used per unit of production constitute the basic factors which must be taken into consideration during the intensification of pond fish culture. Studies undertaken by these authors in 1973-74 in the Ukraine showed that, as a rule deep ponds are characterized by a higher biomass of zooplankton and bottom fauna and by visibly higher productivity compared to shallow ponds. In the sample analysed by the authors fish production in ponds 0.9-1.2 m amounted to 1 514 kg/ha, while in ponds 1.8-2.0 m to 2 294 kg/ha. Furthermore, deeper ponds had a higher survival rate than shallow ones, amounting respectively to 86% and 70.8%. Particular fish species reared in these ponds were also characterized by different weight increments, as illustrated in Table 27.

Table 27

	Depth in m	
	0.9-1.2	1.8-2.0
Carp	574 g	636 g
Bullhead carp	308	446
Silver carp	386	490
Grass carp	503	610

The growth rate of fishes is visibly different in the two groups of ponds, varying from over 10% in the case of carp to almost 45% in the case of bullhead carp. The authors state that in deeper ponds the growth rate was higher although the use of feeds lower than in shallow ponds. And thus FCR (in 1973) reached 2.4-2.6 in deep ponds whereas it reached 3.4-3.6 in shallow ponds. In 1974 the respective values of FCR were 0.6-1.0 for deep ponds and 1.7-1.9 for shallow ones.

Thus, it may be stated that the depth of ponds constitutes a significant factor affecting the economics of fish culture. It is also worth noting that, apart from better fishery and production indices observed in deeper ponds, such ponds are also more suitable for other non-fishery purposes. Obviously there is a limit of pond depth due to the fact that deeper ponds are colder than shallow ones.

It must be remembered that the greater efficiency of fish culture in deeper ponds, compared to shallow ones, is also connected with the higher investments for their construction. There are practically no data that would allow for proper calculation of the profitability of production in both cases. Nevertheless, taking into account the fact that the depreciation of pond construction in most cases constitutes only an insignificant percentage of production costs (rarely exceeding 10%) it can be assumed that additional production benefits resulting from fish rearing in deeper ponds will often exceed the additional costs of constructing such ponds.

References

See references numbered 20, 46, 124, 134, 143, 144.

1.3 Selected Examples of the Economics of Means, Measures, and Methods of Fish Culture

1.3.1 The effect of feeding on the economics of fish culture

Fish feeding constitutes one of the most important factors affecting the production and economic results of fish culture. For many experts feeding represents the basic factor of fish culture intensification, and a criterion for distinguishing between the two essential types of fish culture, i.e., intensive and extensive.

Without going into the complex details of feeding techniques and diet formulae, feeds will be treated as a cost accounting item in this paper.

The role of fish feeding and its effect on the economic effectiveness of fish culture are well exemplified by the data gathered by the Working Party from 24 Polish pond fish farms in 1973 and 1974. The farms are specialized in carp culture and the feeds used are basically cereal foods. Applying the simplest approach it is possible to divide the farms on the basis of average feed cost per 1 ha of area. This way two groups of farms can be distinguished, i.e., those with feed costs either above or below the average. Average production and economic indices for these two groups of farms are presented in Table 28.

More detailed analysis of these farms reveals that an increase of expenditures on feeds by 1 000 zł/ha is connected with an increase of production by 103 kg/ha on the average, whereas an increase of other operating costs results in an increase of production by only 56 kg/ha. The value of production increases by over 4 000 zł/1 000 zł of expenditure on feeds, and by 2 500 zł per 1 000 zł of other expenditures (operating costs). Of course these values serve as specific indices rather than absolute numbers but, nevertheless, they illustrate the significant role of feeding even in carp culture, in which natural food sometimes predominates.

Table 28

Feed costs 1 000 zł/ha	% in operating costs	Production kg/ha	Production kg/employee	Rentability of opera- ting costs in %
Above the average (5.92)	33.7	703.3	6 412	30.7
Below the average (2.48)	26.2	362.0	3 229	-

Another simplified approach was used for the data from 7 Yugoslavian carp farms, gathered by Apostolski (1974) whose results are presented in Table 29.

Table 29

Feed costs 1 000 din/ha	% in operating costs	Production kg/ha	Rentability of opera- ting costs in %
Above the average (5.1)	36.6	1 210	17.8
Below the average (3.0)	23.8	1 003	9.8

The picture resembles the previous case and average production and economic indices in the group with higher feed costs are much more satisfactory than in farms with lower feed costs.

The effect of feeding on the economic efficiency of fish culture is particularly clear when assessing and defining the intensity of fish culture, as illustrated by the Israeli materials (Tal, 1974) (Table 30).

Table 30

Intensity of fish culture	t/ha	Cost of feeds 1 000 Isr.t/ha	% in production costs	Costs of feeds in %	Other production costs in %	Rentability of production in %
Conventional	4.0	7.75	41.2	100	100	12.2
Semi-intensive	8.0	17.35	49.7	224	159	20.9
Intensive	20.0	49.90	53.0	644	400	12.2

Independently of the general increase of production costs in more intensive fish culture compared to less intensive, costs of feeds are characterized by a particularly steep increase. It should be remembered that after exceeding an optimal level, which varies for different conditions, these costs increase the production results of fish culture but decrease its profitability. In the above table the most profitable is the semi-intensive form, and not the intensive one.

Interesting data on the efficiency of carp feeding in pond culture are found in Czechoslovakian literature, particularly since they are based on mass materials. Vevruska (1971, 1972) states that in 1962-1968 in Czechoslovakian farms the use of 100 kg of feeds gave 26 kg of carp production. The favourable relation in that country between cost of feeds and price of carp (1 : 6) results in the high profitability of carp feeding (Vacek, 1974).

In his document prepared for the Working Party (Vacek, 1974 e), as in his other publications (1974, 1975, 1976) Vacek presents an analysis of the effectiveness of carp production in Czechoslovakia in three successive years 1972, 1973, and 1974. Apart from the analysis of mass materials (over 100 ponds in each year) this author selected the ponds with more intensive production, i.e., with per ha gains higher than 0.7 tons which were analysed separately. His results, with slight modifications and recalculations, are presented in Table 31.

Table 31

	Average intensity of farming			High intensity of farming		
	1972	1973	1974	1972	1973	1974
Weight gain kg/ha	454	468	505	844	915	979
Feed costs crowns/ha	1 369	1 582	1 589	2 330	2 833	2 620
% in total cost of production	46.8	48	49.8	41.1	49.7	53.3
Rate of returns %	85	69	89	77	91	133

The decisive role of feeds in the economic and production efficiency of carp farming needs no comment.

Recent Polish studies (Kacza, 1978) on carp feeding also point out its significant role. The author has analysed factors determining the level of catches in different pond types of one Polish fish farm in 1972-1976. The analysis was based on multiple correlation. The farm under study is characterized by a rather high production for Polish conditions, amounting to 1.5 t/ha, and the cost of feeds in total costs of production amounts to about 40%. It appeared that, although the farm under study applies a variety of intensification measures, the variability of catches is mostly determined by the use of feeds; on fry ponds ($C_0 - C_1$) in 47%, on yearling ponds ($C_1 - C_2$) in 74%, and on fattening ponds in 63%.

Similar values were obtained by Worniallo (1977) - about 58-63% determination and by Gordon and Erman (1974) - 53%.

It is worth noting that analyses of the efficiency of fish feeding are usually restricted only to its effect on production results, and do not take into account its effect on economic indicators. In most cases both the inputs and outputs are represented almost exclusively by physical units, such as units of feed per unit area, or units of feed per unit production.

As pointed out by Michailis (1976), in studying the economic effectiveness of feeds it is also necessary to use some economic indicators, i.e., categories of costs (inputs) expressed financially, so as to arrive at some common basis. This is as a result of the fact that at present a whole variety of feeds and feed mixtures are used.

The effect of feeding on the results of fish culture production is extensively discussed in the Soviet literature. This is quite understandable if it is remembered that, in 1972 for example, artificial fish feeding in the USSR gave about 70% of market fish mass and the cost of feeds amounted to almost 50% of the total production costs for inland fish culture (Penchenko S., Prokhovskaya, 1974).

Korolev (1975 a) analysed the relationship between costs of feeds and production results in 70 fish farms. His results are presented in

Table 32

Costs of feeds rubles/ha	107.7	213.2	291.5	387.6
Carp production kg/ha	270	690	930	1 170
Costs rubles/kg of fish	0.40	0.31	0.31	0.33

Based on Korolev (1975 a)

Attention should be given to the relatively low efficiency of feeding at the lowest and highest costs of feeding per 1 ha. The reasons for this are quite different in each case. In the first case the catch per unit of area is rather low. Hence, it can be assumed that low efficiency of feeding results from the unsatisfactory state of pond maintenance. In the second case we are dealing with the general phenomenon of increasing use of feeds along with increasing intensification of production. This trend may also be illustrated by the results of the same author (Korolev, 1975 b) obtained in 1968-1973 in the course of an analysis of state fish farms in the Soviet Federation (Table 33).

Table 33

	Average use of feeds in t/ha			
	up to 3.0	3.1-4.0	4.1-5.0	over 6.0
Average use of feeds in kg/ha	1 940	3 590	4 300	6 670
Fish production in kg/ha	780	990	1 260	1 410
FCR	2.4	3.6	3.4	4.7

The strict dependence of production on the amount of feeds used was also stressed by Murin and Grobokopatel (1968), as illustrated by Table 34, based on the data presented by the two authors.

Table 34

Group of farms with fish catch in kg/ha	Amount of feeds used kg/ha	FCR
up to 200	430	3.2
200-400	1 290	3.9
400-800	2 410	3.6
over 800	4 190	3.4

The authors state that fish feeding constitutes one of the basic measures of the intensification of pond fish culture. This is also supported by data presented by Galasun and Grobokopatel (1973) dealing with the intensification of pond production in the Ukraine. The farms were grouped according to the production costs per 1 ha, and the resulting production and economic indices are presented in Table 35.

Table 35

Group of farms with production costs in rubles/ha	Feeds kg/ha	% of feed costs in production costs	Fish yield kg/ha	Ratio between production value and production costs
	a	b	c	d
up to 300	570	22	326	0.9
300-600	1 620	29	759	1.2
600-900	3 050	35	935	1.3
over 900	5 470	32	1 531	1.4

Note: Values in column "a" and "b" refer to fattening ponds, while "c" and "d" to the total production of the same farms

The dominant effect of feeds in the total cost structure and the greater more intensive increase of feed costs compared to other cost items, along with increasing intensification of production, is quite obvious. Apart from some specific cases, the dominance of feed costs in the total costs of production is regularly observed in almost all forms of fish culture, as illustrated by Table 36.

Table 36

Kind of production	% of feed costs in production costs	Author
Pond fish culture in the USSR in 1969 (mainly carp)	35.5	Murin (1972)
Belorussia, as above	40.0	Murin (1972)
Uzbekistan, as above	44.1	Murin (1972)
Yugoslavia, 1973 (carp)	31.4	Apostolski, Arsovski (1974)
Hungary, 1973 (carp)	43.4	Dobrai (1975)
Poland, 1969 (carp, ind. farms)	48.4	Krzynek (1971)
Poland, 1975 (carp, intensive farms)	40.8	Lech (1976)
Poland, 1962-68, carp	30.0	Kozun (1970)
Poland 1969-70, carp farms (5)	40.0	Moderki, Szamborski (1972)
USA, channel catfish, ponds, 1975	33.0	Brown (1976)
Rainbow trout, as above	33.5	Brown (1976)
Channel catfish, raceways, as above	38.2	Brown (1976)
Rainbow trout, raceways, as above	34.8	Brown (1976)
Channel catfish, cages, as above	51.8	Brown (1976)
Rainbow trout, cages, as above	39.2	Brown (1976)
Yugoslavia, trout, concrete ponds, 1973	55.2	Apostolski, Arsovski (1974)
Catfish, cages, raceways, enclosures	55.5	Collins, Delmendo (1976)
Channel catfish, average manag., USA	50.8	Rabanal, Shang (1976)
Channel catfish, intens. manag., USA	51.2	Rabanal, Shang (1976)
Yugoslavia, pond culture, 1968	36.4	Pazur (1970)
Poland, 20 carp farms, 1966/67	39.0	Szamborski (1969)
USSR, pond culture	30-45	Shabalín (1975)
Czechoslovakia, rainbow trout, cages	34.2-56.9	Vacek (1975 a)

In practice the most frequent percentage of feed in total production costs ranges from 30 to over 50% independent of the form of fish culture. Feed costs increase along with the increasing intensification of fish production. This is caused mainly by two reasons:

- decreasing role of natural food along with increasing intensification of production, and
- relative decrease of fixed operating costs along with increasing intensification.

The latter point is closely connected to the fact that (within broad limits) a significant increase in feed costs does not decrease rentability and may even increase the rentability of production. This phenomenon is very significant from the point of view of economic efficiency of fish culture. It may be illustrated by tables presented in this section and also by the calculation of the unit cost of carp production in Poland in 1962-66 (Kozun, 1970), based on empirical data presented by Szamborski (1969). In order to obtain a clear picture this calculation does not take into account other variable costs, which did not exceed 15% and hence could not have affected the regularity, but was focused only on feed costs (Table 37).

Kazun (1970) states that "... decreasing fixed costs cancel out the increasing costs of feeds to such an extent that the unit cost of fish production also decreases" (Table 37). It should be noted that in the situation analysed by this author only a threefold increase in the costs of feeds would result in an increased unit cost of production. The dominant share of feed costs in total production costs coupled with the fact that feeds constitute the most potent intensification measure and frequently determine economic effectiveness, clearly illustrate that any improvement in feeding and feeds is tantamount to improved economic efficiency of fish culture.

Table 37

Amount of feeds used in kg/ha	Average fish yield (kg/ha)	Costs of the production of 1 kg of fish in zł		
		Feed costs	Fixed costs	Total
up to 400	191	5.54	14.00	19.54
400-500	221	6.56	12.10	18.66
500-600	237	7.17	11.29	18.46
600-700	292	7.10	9.16	16.26
700-800	330	7.17	8.11	15.28
800-1 000	406	7.10	6.59	13.69
1 000-1 500	512	7.36	5.22	12.58
1 500-2 100	711	8.42	3.76	12.18

Generally speaking, a decrease in the cost of feeds can be achieved in the following ways:

- (i) By the use of similarly effective but cheaper feeds and feed mixtures. Such an approach is exemplified by Soviet studies on trout feeds. It appeared that by lowering the content of animal proteins in trout pellets from 34.2% to 14.3%, accompanied by an increase in plant protein content from 6.3% to 23.8%, the cost of the unit weight increment decreased by 40%, and the consumption of animal proteins by 50% (Kanidiev and Gamygain, 1975).
- (ii) By supplying traditional feed mixtures with valuable components. An interesting example of this approach is presented by Apazioli and Tarasov (1975). The paper does not contain any economic calculations, but the authors state that the additive used is quite cheap. In this case a traditional carp food mixture was enriched by a 10% addition of protein and vitamin concentrate, synthesized in micro-organism culture on saturated hydrocarbons. The results were as in Table 38.

Table 38

	Production kg/ha	Final individual fish weight (g)	Survival in %	% of protein in fish flesh	% of edible parts
1970 control	695	351	75.2	-	100
experiment	1 100	438	80.2	-	105.8
1973 control	660	574	95.4	14.44	100
experiment	1 000	653	99.7	15.75	112.8

It should also be noted that in this case the quality of production also improved.

- (iii) By simultaneous application of other intensification and biotechnical measures. As stated further on, only through selection is it possible to decrease the use of feeds by as much as 30% while the use of larger stocking material (10 g and 50 g) can decrease the use of feeds by 17-24%. Korolev (1975) points out that by taking into account the fish losses occurring during the production cycle and decreasing the amount of feeds used accordingly, it is possible to save 15-20% of the total amount of feeds annually. Also, the stocking rate must obviously be adapted to the amount of feeds used.
- (iv) By proper feeding methods as regards the feeding rates on a daily and annual cycle. In the latter case attention must be paid to water temperature and when the culture is partly based on natural food, also to the seasonal variation of natural food resources.
- (v) By proper selection and improvement of the production basis. Such problems are discussed in other sections of this paper but it is worth mentioning here that in an extreme case of carp culture in one Polish lake specially adapted for this purpose, at fish return amounting to 74% of the stocking rate, the following production and economic indices were obtained (Kossakowski, 1969): carp catch in kg/ha - 276; FCR - 1.51, percent of feed cost in total costs of production - 5.38; rentability of production - 29.2%.

It should be noted that this is a fairly typical example of the possibilities for fish culture development, characterized by high economic effectiveness without practically any costs of investments.

References

See references numbered 17, 23, 44, 50, 60, 63, 70, 71, 73, 75, 81, 85, 101, 104, 107, 109, 113, 115, 121, 130, 150, 160, 161, 162, 163, 163bis, 164, 181, 188, 189, 192, 197, 198.

1.3.2 The effect of fertilization on the economics of fish culture

The question of fertilization in fish culture, and especially in pond fish culture, is probably one of the most frequently discussed topics in the literature. Winberg and Lakhnovich (1968) in their monograph on pond fertilization cite about 500 references.

It is difficult to define the effect of fertilization on the economic effectiveness of fish culture for at least three reasons:

an almost infinite number of various combinations of fertilizer use, and different methods of application,

unsatisfactory knowledge of the mechanisms underlying the real effect of fertilization on fish production,

lack of economic indices in discussing the use of fertilizers by most authors.

To illustrate the point - in the above cited monograph by Winberg and Lakhnovich (1968) less than 10% of the volume of this book is devoted to the broadly understood economic efficiency of pond fertilization. As a result it is possible to find production indices of the effectiveness of fertilization, while it is almost impossible to find any economic indices. To a certain extent this is understandable, since as a rule costs of fertilizers constitute only a small percentage of total production costs. In the case of some fish species (e.g., trout) they are totally absent, while in the case of others they decrease considerably, or even disappear, along with increasing intensity of fish culture based mostly on feeds. Among the materials gathered by the Working Party only in one case of average intensity of farming in Czechoslovakia (Vacek, 1974) does the cost of fertilizers amount to 7% of production costs; in all other cases it ranges between 0 (intensive culture in Israel, Tal 1974), and 14.3% (high intensity of farming, Czechoslovakia, Vacek 1974).

Nevertheless, the importance of pond fertilization in carp culture in Czechoslovakia (Krupaer 1973) is reflected in several interesting papers dealing with this problem. Vavruska (1972) has made a statistical analysis of materials from the period 1962-68 for all ponds in Czechoslovakia and found that:

application of 1 kg of P gives an increment of fish production of 1.635 kg; 11.45-12.85 kg per 100 kg of superphosphate,

application of 100 kg of organic fertilizers gives an increment of 0.76 kg,

breeding of 100 kg of ducks for slaughter gives an increment of 13.4 kg of fish production or 100 birds/1 ha give an increment of 31.5 kg/ha.

Unfortunately, this author did not make any economic calculations, either in the paper mentioned above or in any other.

Pond fertilization is extensively discussed in the Soviet literature. Babalan and Gordon (1968) state that optimal doses of fertilization can increase the natural productivity of ponds two to three times. According to these authors 1.5 kg of ammonia saltpetre and 2 kg of superphosphate are used to obtain a 1 kg increase of fish production. The cost of these fertilizers is half as much as the cost of feeds needed to obtain the same weight increment. The same authors present several examples of the efficiency of fertilization. For instance, in Belorussia production of 710 kg/ha was obtained without any feeding but with fertilization it amounted to 140 kg/ha of ammonia saltpetre and 120 kg/ha of superphosphate. It is another example, in a 900-ha farm, an increase of fish production from 270 kg/ha to 456 kg/ha was obtained based only on fertilization at the level of 562 kg/ha. It is worth noting that 3 kg of fertilizers were used in this case for every 1 kg increase of production.

Based of the results obtained in a Belorussian farm, in which fertilization doubled or tripled fish production, the authors stated that the same increase of production achieved though artificial feeding would cost about three times as much. Cygankov *et al.* (1974) cited the results of studies in which 1 t/ha of sylvinite (potassium fertilizer) and 0.5 t of ammonia water were introduced into carp fattening ponds before filling them with water. Compared to control ponds, production in experimental ponds was 23.5-35% higher and the individual weight of fishes reached 569-615 g (463 g in control ponds). The authors concluded that this measure was economically very feasible. Due to fertilization the resources of bottom food organisms increased to 1.5-2 times compared to control ponds.

According to Demchenko and Shpet (1973) results obtained by some Ukrainian fish farms showed that pond fertilization based on scientific grounds, coupled with proper selection of cultured species can increase natural productivity of ponds by up to 100 kg/ha or more.

The visible economic effects of fertilization are stressed by Sidorov (1974) as regards two ponds over 100 ha with different level of fertilization (Table 39).

Table 39

	Pond No. 1	Pond No. 2
Fertilization(kg/ha)	460	900
Fish catch(kg/ha)	1 190	1 250
Survival rate(%)	67	77
FCR	4.4	2.2
Cost of feeds and fertilizers per 1 kg of fish weight - rubles	0.29	0.179

In this case fertilizers substituted for artificial feeds and as a result production cost decreased considerably. The author states that in pond No. 2 over 14 000 rubles were saved (cost of producing 1 t of fishes amounted in this farm to 551.4 rubles).

Altukhov (1976) has undertaken extensive studies on the efficiency of fertilization in pond fish farms in Western Ukraine. His results showed that by fertilization it is possible to increase the natural productivity of ponds to 550 kg/ha, i.e., to the level representing a net income of 996 rubles/ha. Recalculation of data given by this author shows that the ratio between additional fish production resulting from fertilization and the cost of fertilization is 2.89:1 in fattening ponds, and 5.64:1 in rearing ponds (the average ratio for all ponds being 3.27:1).

Kacza (1978) has analysed the efficiency of fertilization in one Polish pond farm which uses large amounts of fertilizers, at a rate of about 1 000 kg/ha of NPK in pure components. The same farm was also analysed by Lech and Kisielewski (1976). It was calculated that the ratio between additional fish production and cost of fertilizers in this farm amounted on average (for all ponds) to 4.3:1.

Problems of fish pond fertilization, with special attention being given to the use of organic fertilizers (including waste) has been studied in Israel. Unfortunately, most papers fail to give any economic analysis of this problem. Allen and Hepher (1976) state that "... there are only few instances of documentation of income from production of a product in waste water aquaculture system", and that "... until this is done, a complete cost-benefit analysis can not be made". This statement is true of the whole problem of fertilization in aquaculture.

In view of the above, the calculation of rentability of the use of various fertilizers, given in the paper by Rappaport et al. (1977) seems to be very much worth citing. The calculation refers to carp farming in 1976 (Table 40).

Table 40

Type of fertilizer	Chicken droppings	Liquid manure	Chemical fertilizer	Control
Yield of 3 seasons (kg/ha)	5 564	5 050	4 710	4 472
FCR including fertilizer	3.24	3.85	3.74	4.05
Cost of fertilizer (Isr.f/kg of fish)	0.16	0.54	0.13	-
Cost of feed + fertilizer (Isr.f/kg of fish)	4.21	5.01	4.87	5.26
Income (Isr.f/ha)	55 640	50 500	47 100	44 720
Cost of feed + fertilizer (Isr.f/ha)	23 410	25 270	22 900	23 530
Contribution after deduction of feed and fertilizer (Isr.f/ha)	32 230	25 230	24 200	21 190
Contribution as % of control	152	119	115	100
Difference in yield as % of control	124	113	109	100

After Rappaport et al. (1977)

Index of the value of additional production, obtained as a result of fertilization, calculated in relation to cost of fertilization, is presented below:

chicken droppings - 12.3

liquid manure - 2.1

chemical fertilizer 3.9

It should be pointed out that apart from the totally different conditions of fish production in Israel, the above index remains more or less within the range calculated for the Ukraine and Poland. High production and economic efficiency of fertilization in pond fish culture is quite clear from the above example. Nevertheless, it should be emphasized that this problem has not been dealt with satisfactorily in the literature, although its importance is growing rapidly, exceeding even the limits of strictly economic analysis. As stated by Schroeder (1973) "At a time when fish meal and other sources of protein for animal feed are in even more short supply, it is prudent to consider ways of increasing the abundance of natural protein sources in pond water. This is true for normal as well as intensive aquaculture".

References

See references numbered 1, 2, 8, 25, 29, 60, 80, 84, 122, 126, 138, 164, 197, 198.

1.3.3 The effect of other biotechniques on the economics of fish culture

Specific methods of fish farming can sometimes significantly affect its economic efficiency even within the context of traditional fish culture, not to mention the strictly industrial form. This is exemplified by a method of wintering fish fry in tanks worked out in the Soviet Union (Kanaev, 1974; Osetrov, 1975; Trifinov, 1976). The system is based on wintering the stocking material (mainly carp fry) in specially constructed concrete tanks with water exchange, aeration, introduction of medicines and disinfecting agents, mechanical purification, etc.

Experiments carried out on a production scale showed that at a stocking rate of 75 million carp fry, ha losses amounted to only 4-10%, while in normal conditions within the Soviet Federation, at a stocking rate of 0.3-0.5 million individuals/ha, losses usually reached 25-40%. The cost of veterinary services decreased 30-50 fold without taking into account its increased efficiency. Economic calculations showed that costs of construction of complex adapted for wintering 1 million fry amounted to 45-60% of the traditional methods, without taking into account decreased land requirements; the surplus of land area may be then used for market fish production (Osetrov, 1975), and the rate of return on investments does not exceed two years (Kanaev, 1974). Introduction of the new method on a production scale gave similar results in all cases, and its economic benefits were continually underlined (Pateeva, 1976; Klimenko, 1976; Gsrin, 1976).

In our geographic conditions the time necessary for producing market fish represents an especially important consideration. In carp culture, despite several successful attempts at shortening the cycle to 1.5 or even one year, 2- or 3-year cycles still predominate (Apostolski, Arsovski, 1974; Vacek, 1974; Krupaer, 1973; Polish materials, 1974; Kozum, 1973; Gordon, et al., 1975).

Analysis of the profitability of the two cycles was made for Polish fish farms by Kozum (1973). She found that it is practically impossible to foresee which system will be more effective in a given situation. It was found that, in practice, these two systems are commonly used as complementary methods, depending on the quality and number of spring fry in a farm. Production and economic efficiency of both systems in relation to the weight of fry is given in Table 41, calculated per unit fry. Apart from the obvious effect of initial fry weight on the efficiency of fish culture, it is very difficult to state which system is more effective.

Table 41

	Production in kg	Value of production in zł
Fry 34 g		
2-year cycle	0.220	4.62
3-year cycle	0.356	10.42
Fry 56 g		
2-year cycle	0.443	11.48
3-year cycle	0.433	12.68

Based on Kozum (1973)

Godon et al. (1975) analysed the efficiency of pond farming in the north-western region of the USSR and found that the 3-year cycle was more effective. Their results are presented in Table 42.

Table 42

	2-year cycle	3-year cycle
Production (kg/ha)	603	776
Operating cost (rubles/ha)	448	557
Capital investments (rubles/ha)	3 799	4 097
Profit (rubles/ha)	28	265
Rentability of capital investment (%)	0.74	6.47
Rentability of operating costs (%)	6.2	47.6

Based on Gordon *et al.* (1975)

The difference between the two systems (Table 42) are rather striking: for an increase in operating costs by 24% and of capital costs by 8%, profit increased almost tenfold, rentability of capital investment about 9 times, and rentability of operating costs over 7 times.

Beliaev (1976) gives an interesting example of results obtained in a Belorussian fish farm after the introduction of a 3-year cycle. It should be noted that this fish farm was created mainly in order to provide water retention for agriculture and consists of rather large (140-270 ha) and deep (up to 4 m) ponds. Results obtained by this farm in a 2-year cycle of carp production and results obtained after the introduction of 3-year cycle, are illustrated by Table 43.

Table 43

Period	Production kg/ha	Cost of unit production rubles/100 kg	% of 3-year old carp in total production	Profit (rubles/ha)
1967-1969	195	85	-	-37.2
1970-1972	733	61	59.7	93.8
1973-1975	1 177	54	76.6	225.6

Although no economic calculation was made, the results presented in the table point to the higher efficiency of a 3-year production cycle compared to a 2-year cycle.

Syrov, Kosodoeva, and Voroshilina (1977) state that the advantages of a 3-year cycle consist of better nutritional product quality, resulting from the difference in fish weight. Their studies showed that fish produced in a 3-year cycle reached an individual weight of 1 170 g while in a 2-year cycle - about 400 g, and that in a 3-year cycle the fish meat had 68.4% higher calorific value than in a 2-year cycle (in relation to 1 kg of weight).

Production practice has also evolved a particular system of fish culture based on a 2-year water cycle. This is useful in farms characterized by water shortage as well as for carp dropsy infection, which is usually exacerbated by excessive fish handling. In this system water is drawn off from ponds every 2 years. The classical scheme, based on a 30-ha pond, which has been under observation since 1946 (Szczerbowski, 1977) is as follows:

A pond dried in autumn after the fish harvest, undergoes running repairs in the following spring, i.e., drainage ditches and fishing areas are dredged, the pond bottom is mechanically cultivated, and slaked lime applied at the rate of 0.5 t/ha. At the beginning of the summer the pond is slowly filled with water. When the water level reaches a certain percentage of its total volume, the pond is stocked during July with small carp hatchlings weighing a few grammes or less, at the rate of about 5 500 individuals/ha. Commercial size fish are harvested in November the following year. During the 2-year breeding cycle 6 t of feeds are used altogether per 1 ha; 20% in the first year, the rest in the second year. 90% of feeds consist of cereals, mainly their waste products. Fertilization is rather low, amounting to about 30 kg of NPK per 1 ha. If unfavourable changes are noted in the environment slaked lime is spread over the water surface.

In the above mentioned pond, the 2-year system already gave a significant increase of production in the first 2 years. Increase of production reached over 90% compared to the traditional system, based on yearly drying of ponds, and stocking with 50 g fry after wintering in other ponds. In the pond under discussion fish production increased from 362 kg/ha in the traditional system to 656 kg/ha in the 2-year water cycle system. Continuous improvement of the system resulted in the above situation, with production remaining at a relatively constant, high level. Over the last 10 years (1967-1976) production indices were as follows: average stocking rate per 1 ha - 4 850 hatchlings, average fish catch per 1 ha - 1 216 kg, average individual carp weight - 0.8 kg, survival rate - 62%, and amount of feeds used per 1 kg of market fish - 2.53 kg.

The economic implication of this is clear even without any more precise economic assessment, especially if we compare the above results in the last 10 years with corresponding data from traditional systems. For instance, in 1976 it was necessary to use 78.4% more stocking material, 25% more feeds, and 7% more fertilizers in order to obtain the same level of production. Finally, the 2-year water cycle system is characterized by significantly lower labour requirements, which are roughly 50% less than in the traditional system.

The above is not an isolated example: in 2 other cases cited by the same author (Szczerbowski, 1977) increase of production compared with the traditional system of yearly pond drying amounted in the last 6 years to 58.1% and 79.9% on average. It should, however, be underlined that the system under discussion does not give satisfactory results if breeding and cultivation conditions are not maintained at the proper, high level. Nevertheless, it seems that the system can offer good prospects for the future due to its undoubted value in terms of both production as well as non-fishery and non-production benefits "saving of water". It should be especially valuable in those European regions which are characterized by maximal summer rainfall in June.

References

See references numbered 14, 42, 47, 52, 62, 67, 76, 80, 112, 147, 151, 155, 188.

1.3.4 The effect of stocking rate on the economics of fish culture

Along with feeds, fish stocking rate constitutes one of the main factors affecting the economic efficiency of fish culture. In many cases, the cost of stocking material represents a dominant item in the structure of operating costs. This cost is not always apparent due to the fact that it is not usually taken into account in farms which produce their own stocking material. In the latter case it is assumed that it occurs on both sides (i.e. expenditure and results). This has been noted, for instance, in the case of Polish fish farms, and most probably also in Hungary and Czechoslovakia.

Nevertheless, there are many cases where the costs of stocking material are specified. Their share in operating costs is presented in Table 44.

Table 44

Type of culture	% in operating costs	Author
Carp farms, Yugoslavia, 1973	22.5	Apostolski, Arsovski, 1974
Trout farms, Yugoslavia, 1973	13.4	Apostolski, Arsovski, 1974
2 carp farms, Poland, 1969/70	28.4	Moderski, Szamborski, 1972
FRG, carp $C_0 - C_v$	42.8	Lukowicz, 1974
FRG, carp $C_v - C_i$	55.6	"
FRG, carp $C_i - C_{ii}$	37.8	"
FRG, carp $C_i - C_{ii}$ intensive	34.9	"
FRG, carp $C_{ii} - C_{iii}$	34.1	"
FRG, $C_{ii} - C_{iii}$ intensive	32.8	"
Channel catfish, ponds, 1975	16.0	Brown, 1976
Rainbow trout, ponds, 1975	41.0	"
Channel catfish, raceways, 1975	14.6	"
Rainbow trout, raceways, 1975	42.5	"
Channel catfish, cages, 1975	19.8	"
Rainbow trout, cages, 1975	47.7	"
Trout farm, Poland, 1973	22.0	Wisniewska, 1977
USSR, carp farms, 1969	18.5	Murin, 1972
Belorussia, as above	14.1	"
Lithuania, as above	31.6	"

The high proportion of the cost of stocking material in the total costs of production has given rise to a certain amount of literature dealing with the role of stocking rate in fish culture. In many cases this role is even overestimated. For instance, traditional opinion states that the multiplicity of standard stocking rate and/or the density of fish stock per unit of area can constitute a measure of the intensity of a particular form of fish culture. (Wieniawski, 1965; Murin, 1972; Murin and Grobokopatel, 1968). Such an approach is an obvious oversimplification, based on the common assumption that stocking rate is connected with the level of other expenditures, and that production and its economic effects result from stocking rate.

However, the whole problem is rather complicated. As pointed out by Kurovskii (1971) there is a very complex interrelationship between stocking rate, fish production, and individual weight of fishes at harvest. Similarly as in the case of many other fish culture operations, authors analysing this problem usually take into consideration only the effect of stocking rate on fish production indices, without paying attention to the economic aspects. Nevertheless, the significant effect of stocking rate on the economics of fish culture comes out indirectly even in such papers. For instance, Galasun and Grobokopatel (1973) analysed the effect of fish stocking rate in fattening ponds in the Ukraine on production indices. Their results are presented in Table 45.

Table 45

Stocking rate 1 000 indiv./ha	Production kg/ha	Indiv. weight of market fish (g)	FCR
up to 2	459	329	4.7
2-3	757	369	4.4
3-4	846	333	4.8
4-5	1 177	325	4.5
over 5	1 720	301	4.9

The authors state, that, apart from an increase of fish production, two other phenomena are noted along with the increasing density of fish stock, both being clearly unfavourable. They comprise a decrease in individual weight of harvested fish and an increase of FCR. This is supported by data obtained from 102 ponds belonging to a fishery combine, presented in Table 46.

Table 46

Stocking rate 1 000 indiv./ha	Production kg/ha	Indiv. weight of harvested fish (g)	Survival rate (%)	FCR
up to 2.5	799	416	92.3	3.60
2.5-3	1 050	441	88.9	3.89
3-3.5	1 339	467	90.4	3.93
3.5-4	1 537	429	93.0	4.40
over 4	1 208	327	75.9	4.40

As may be assumed based on Table 46, in extreme cases, excessive density of fish stock may lead to a decrease in survival rate, or even to a decreased fish production expressed in absolute value per unit area. However, it should be underlined that the authors did not take into account the individual weight of stocking material, while this factor may significantly affect production and economic results of fish culture.

Grobokopatel (1976) states that excessive density of fish stock in the production of stocking material results in a decrease of individual fish weight, as also in an increased amount of feeds used per unit of production. Results of experiments undertaken in a pond combine showed that an increase of stocking rate in fry pond from 80 000 individuals/ha to 120 000 individuals/ha, i.e., 1.5 times, increased the production only 1.2 times, while the average individual weight of fishes decreased by 14.9%, and the use of feeds increased by 29.7%. Further increase of stocking rate, up to 160 000 individuals/ha resulted in a drop of production by 29.2% and an increase in the use of feeds by 78.4% per unit of production. Economic analysis showed that if costs of "materials" used at a stocking rate of 80 000 individuals/ha were taken as 100%, at stocking rate of 120 000 individuals/ha they increase to 127%, at 160 000 individuals/ha to 222%, whereas the cost of feeds increased to 130 and 178% respectively.

The effect of stocking rate on the results of production is also of economic importance. This has two effects: firstly, at an increased stocking rate the individual weight of fishes (stocking material) - decreases, which in turn has a negative effect on production and economic results. Secondly, in the case of market fish production, the individual weight of harvested fish also decreases. The latter point should be discussed more thoroughly, as it is closely connected with a most promising approach to the assessment of fish culture efficiency involving energy requirements and outputs (Edwardson, 1976; Bardach, 1978).

Babaian and Gordon (1968) stated that the nutritive value of 300 g carp is 6-8% lower than that of 400-450 g carp due to a worse ratio between edible and non-edible parts, whereas the calorific value of 300 g carp is 10-15% lower than 400-450 g carp.

According to Martyshv (1973) in 2-year old, fully scaled carp, weighing 320 g, edible parts constitute only 44.6%, while in 500 g carp about 60%. The consequences of such a broad, ecological and economic approach are extremely significant. For similar levels of production, at a similar level of expenses, real efficiency of production (in energetic units) will be 34% higher in the second case than in the first. And it is assumed that expenses are similar in both cases, so the real efficiency of the production of heavier carp is automatically underestimated.

Maslova (1973) criticizing the method of defining the quality of fishes on the basis of their calorific value, pointed out that in numerous cases this measure reflects only undesirable fat content. She also underlined the effect of stocking rate on the protein content of fishes. As a result of several experiments, she found that at a stocking rate 5 times higher than the control, the results of production were lower than anticipated by 406 kg/ha of fish and 15 kg/ha of protein. At a stocking rate 10 times higher than the control, the respective losses amounted to 1 542 kg of fishes and 175.6 kg of protein, while at 15 times higher stocking rate - to 2 718 kg of fishes and 332 kg of protein, although fish feeding was adjusted according to fish stocking density. According to this author, these differences were due mostly to differences in the individual weight of fishes. When smaller stocking material was used the results were even worse.

Similar results were obtained by Maslov (1973) for the production of carp fry at stocking rates 5, 7, and 10 times higher than the control (Table 47).

Table 47

Stocking rate	5 x control	7 x control	10 x control
Gain of fish production (t/ha)	3.18-3.32	3.04-3.08	2.53-2.74
Average fry weight(g)	38.9-40.8	25.6-26.6	16.0-17.4
FCR	3.4-3.5	3.45-3.6	3.91-4.05

Based on Maslov (1973)

The economic aspects of these results are obvious. Apart from the fact that lighter fry will subsequently lower production results, costs of feeds for producing the same mass of fishes are in the extreme case almost 25% higher.

Balashova, Galasun, and Kharitonova (1975) state that at similar production levels for carp in kg/ha, the difference of average individual weight (256 g and 451 g) resulted in significant differences of fish quality. 451 g carp was characterized by higher content (by 13% on average) of edible parts, in which were 10% higher protein content, 20% more fat, and 9-10% more mineral salts. The authors point out that their previous experiments (Galasun, Kharitonova, and Balashova, 1971) showed that the individual weight of market carp was determined by stocking rate. It seems that in order to make the assessment of fish culture more objective and reliable, it would be necessary to introduce into the analyses, not only the financial value of production, but also the quality of the product.

References

See references numbered 8, 11, 17, 39, 44, 45, 53, 82bis, 92, 96, 98, 99, 104, 107, 109, 130, 169, 172, 188

1.3.5 The effect of the size of stocking material and rearing systems on the economics of fish culture

The stocking rate has been frequently dealt with in the literature. It is also commonly used as the measure of the intensity of production (Studeniskii, 1976, Galasun and Grobokopatel, 1973, Murin, 1972). On the other hand, the individual size of fish stocked is usually taken into account only in the case of stocking material of different age. Meanwhile, the individual size of stocking material significantly affects the efficiency of fish farming, as exemplified in Table 48

Table 48

Indiv. size of fish stocked (g)	Number of stocking materials per 100 kg of market fish		Cost of production of market fish in rubles		Profit per 100 kg of market fish in rubles		FCR	% of benthic organisms in bulk
	1972	1973	1972	1973	1972	1973		
Year								
10	414	467	69.8	91.5	20.2	-14.0	3.6-3.8	16.7
25	213	226	59.0	64.3	30.2	25.7	3.4-3.5	21.1
50	159	157	53.6	54.5	35.5	36.4	2.8-3.0	27.8

According to Kostiaikov (1975)

In 1972 stocking rate amounted to 2.0 thousand individuals/ha and in 1973 to 2.5 thousand individuals/ha. Production and economic results were quite different depending on the individual site of stocking material, although stocking rate and production conditions were similar. It should be pointed out that without taking this fact into consideration one could draw completely erroneous conclusions.

Murin (1972) points out the influence of the individual size of stocking material on the rate of growth and final size of market fish. He states that studies carried out in different geographical regions showed that there was a proportional relationship between the individual weight of stocked carp and the rate of growth. To illustrate the relationship the author cited the results of some experiments (Table 49).

Table 49

Average individual weight of fry in g	7.5	12.5	25	40	60
Average individual weight of 2-year old carp in g	314	365	436	522	591
Weight increment in g	306.5	342.5	411	482	531

The same author also cited the results of some experiments by Shpet, who found that in similar conditions the individual weight of 2-year old carp obtained from 16 g stocking material amounted to 470 g, while from 43 g stocking material to 830 g (Murin 1972). This is supported also by the results of studies by Galasun and Kharitonova (1975) which showed that in similar conditions, and at the same stocking rate, carp fry stocked at an individual weight of 13 g reached 280 g, at harvesting while 24 g fry reached 400 g.

The effect of the individual size of stocking material on the results of fish farming is also connected with lowered resistance of smaller fish to wintering conditions. Murin (1972) presented the following table (Table 50).

Table 50

Average individual fry weight in g	Losses during wintering in %
up to 10	72
10-15	50.4
15-20	35.5
20-30	16.6
over 30	9.6

Kacza (1978) has used correlation analysis for 142 fattening ponds in one Polish fish farm where average production reached 1 420 kg/ha. He found that there was a highly significant statistical correlation between the level of production and individual weight of stocking material. The bigger the fish stocked, the higher the production of market fish per unit area. Further studies by the same author (Multiple correlation analysis) showed that the variability of fish yield is on average determined in 20% by the individual weight of stocking material.

In practice, the main problem of fish culture, apart from its form and place, consists of producing the stocking material in high amounts and of good quality. The size of fish used as stocking material, as shown above, determines future production and economic results. This size is mostly conditioned by the rearing system. Without going into the details of rearing techniques, the problem may be exemplified by the differences in production effectiveness between traditional carp spawning and using heated effluents. The results of both methods are presented in Table 51 based on data given by Sim Do Tchek (1975).

Table 51

	1973		1974	
	Artificial spawning	Natural spawning	Artificial spawning	Natural spawning
Date at spawning	18 May	3 June	10 May	8 June
Number of larvae/female in thousand individuals	150	62.6	129	55
Date of pond stocking	25 May	16 June	18 May	21 June
Stocking rate (individuals/ha)	50	50	37.5	37.5
Date of catch	22 Oct.	22 Oct.	3 Oct.	3 Oct.
Individual weight of fishes in g	24.5	12.0	35.0	10.3
Survival rate (%)	65	70	72	86.6
Catch (kg/ha)	790	420	945	335
Growing season (days)	146	126	135	102

The author does not give any economic calculations, but even if the production of stocking material from an artificial spawning were twice as expensive as from a natural one, its economic effectiveness would be even higher. Furthermore, this increased effectiveness remained during the stage of market fish production.

References

See references numbered 44, 46, 60, 74, 107, 139, 145.

1.3.6 The effect of polyculture on the economics of fish culture

The adoption of polyculture, especially carp combined with other species of fish including phytophagous fish, significantly affects the economic efficiency of fish culture. This is above all connected with better utilization of natural food resources in ponds. Results of production obtained in polyculture are higher than in monoculture, and are usually also characterized by more favourable economic indices either due to lower costs of production or to higher profit. Typical examples of the efficiency of polyculture are the results obtained in China, Israel, or the USSR (Rabanal and Shang, 1976). "In the USSR polyculture of carp with phytophagous fish gives additional production of 400-1 000 kg/ha, depending on the geographical area, without any additional feeding" (Rabanal and Shang, 1976). The latter form of polyculture is becoming more and more popular, in our geographical zone also.

Shabalín (1975) discusses one of the best Belorussian farms, pointing out that the high production and economic results obtained in this farm are due to polyculture, and thus to better utilization of natural food resources in ponds. Economic appraisal of the results obtained from polyculture of carp with plant feeding fishes was made by Dukhnovskii (1970) for a pond farm in the Ukraine. Cost and economic results of this farm are given in Table 52.

Table 52

Production	kg/ha	Operating costs rublas/ha	Rentability of operating costs in %
Carp	690	544.5	14.0
Phytophagous fishes	190	122.2	37.8
Total	880	666.7	18.4

Based on Dukhnovskii (1970)

The introduction of plankton-feeding fishes gave 27.5% of additional production (compared to previous carp monoculture), and a 31.4% increase in the rentability of operating costs, while total costs of production increased by only 22.4%.

Korolev (1965) made an analysis of 63 pond farms in the northern Caucasus and neighbouring regions. The author found that there was a close link between the degree of polyculture development and the unit cost of fish production. The higher the degree of polyculture development, the lower the unit cost of production, especially the cost of feeds. The author illustrated this relationship comparing particular fish farms, which differ as regards the share of carp in total fish yield (Table 53).

Table 53

	Group of farms			
	I	II	III	IV
Share of carp in fish yield in %	34.2	50.0	70.3	88.6
Unit cost of fish production in % in relation to group IV	73.0	84.3	97.3	100

Dukhnovskii (1972) analysed the effects of polyculture of carp with plant feeding fishes in a large pond farm near the Don River. He states that in 1969 average production of market fish ponds increased by 12% as a result of polyculture, whereas in some ponds this increase reached even 20-30%. The author presented an economic calculation for one pond. Average rentability of total fish production in this pond reached 27.5%: 18.3% for common carp, and 42.4% for silver carp. Analysing the same farm in 1972 Dukhnovskii (1974) noted that in 1965-1972 production in market ponds almost doubled (from 1 440 kg/ha to 2 800 kg/ha), and that this increase was caused only by the introduction of polyculture. In 1972 total fish production of the farm amounted to 2 800 kg/ha, of which 960 kg/ha, i.e., 34% were presented by plant-feeding fishes.

The high economic efficiency of polyculture compared with monoculture was also underlined by Lebedeva (1970). Her partial economic analysis showed that the introduction of polyculture of carp with phytophagous fish in some pond farms increased the total cost of production to 231% (compared to carp monoculture) but the effectiveness of additional expenditures on polyculture reached 352%.

It should be added however that polyculture is not always connected with high economic efficiency. This is mostly due to the more complicated biotechniques of polyculture which require considerable labour and professional knowledge. Furthermore, polyculture systems require further improvements, such as controlling the density of various species, regulating fertilization, adjustment of species to suitable niches, etc. These factors hinder the wider adoption of polyculture.

References

See references numbered 34, 35, 36, 71, 83, 121, 130.

1.3.7 The effect of the period of pond filling on the economics of fish culture

The various different times when ponds are filled with water are not connected with any additional economic cost. On the contrary, by changing this period it is sometimes possible to decrease cost, and to increase fish production. On the basis of studies undertaken in different climatic zones Bokhtina (1975) states that in breeding ponds used for the production of market fish, it is possible to increase production by 30-40% just by filling the ponds with water in autumn instead of spring. According to this author, autumn filling guarantees an increase of fish production by 100-200 kg/ha, with simultaneous decrease in the amount of feeds used, and a possibility of earlier pond stocking.

According to Chizhik et al. (1973), if ponds are filled in spring about 1-1.5 months of the growing season are lost. On the other hand, if ponds are filled with water and stocked with fish in autumn, it is possible to obtain market fish much earlier. Another value of this method is a significant decrease in labour requirements - the number and area of wintering ponds are smaller and the work in spring is not so intensive. Furthermore, the method provides sufficient resources of food for the fish both in autumn, before the ponds freeze, and immediately after ice melting. Murin (1972) has discussed the value of this method and pointed to the fact that it results in a considerable saving of capital investments since it is not necessary to construct expensive wintering ponds. According to Cygankov and Polgueva (1970), this method most of all decreases labour requirements, and in the long term, results in an average increase of production by about 200-300 kg/ha compared to ponds filled and stocked in spring.

The experiments by Skabichevskii and Smolin (1975) showed that this method can increase fish production by even 300-400 kg/ha.

From an economic point of view the problem is quite important - we are dealing here with a valuable form of the intensification of production, i.e., a method that does not require any additional financial expenditure and can even lower the cost of production and improve the utilization of natural food resources in ponds.

Any significant improvement of natural food in ponds automatically increases the possibility of further intensification by artificial feeding. Furthermore, it should be remembered that natural food resources of ponds are very rich in proteins. Hence, any improvement of natural food is connected with the possibility of using cheaper artificial feeds, such as low-protein cereal feed, resulting in a further reduction in cost. In Poland many fish farms are gradually adopting the new system. However, it is difficult to cite here any precise economic results or what long-term experience may show, because the process is still getting under way.

References

See references numbered 9, 21, 24, 107, 141.

1.3.8 The effect of selection on the economics of fish culture

Introduction of new fish strains can have a significant effect upon the economics of fish culture. Wlodek (1972) states that "... any progress in animal production results from 4 interrelated measures. These measures are: artificial feeding, improvement and shaping of the environment used for animal production, control of diseases, and animal breeding and selection". According to this author the fourth measure constitutes "... one of the 4 basic means of increasing fish production in ponds. It is aimed at a preservation and improvement of fish stock. Consequently, it also constitutes one of the main factors integrating a whole set of different measures affecting fish production".

Despite the high value ascribed to fish selection it is quite difficult to find any studies that directly integrate this factor into economic calculation but it is possible to illustrate its effect indirectly by appropriate biotechnical and production indices.

Murin (1972) and Krasavcev (1975) state that as a result of selection Ukrainian fish farms obtained a new race, the so-called "ramchatyi" carp. Compared to mirror carp this new race is characterized by the following features: 21.4% lower food requirements per unit weight increment, 46% better utilization of natural food resources, 17% higher rate of growth, 25% higher production. This new race is also characterized by higher survival rate.

Hungarian work on cross-breeding Hungarian races of common carp resulted in an introduction of hybrids which, according to Bakos (1976) are characterized by the following features when compared to pure races: 16% higher survival rate until harvest, and at joint evaluation of both first and second year survival they showed 21% better viability, 15-40% better growth, 15-30% lower feed requirements, 3-4% less fat content with intensive feeding. The author concludes that "... on the basis of a collective evaluation of several important characteristics, it was established that by cross-breeding different regional strains of carp, hybrids could be obtained that ensured an improvement of 15-20% in intensive fish farming with minimum financial expenses".

It should be underlined that practical use of selection in order to improve the economic efficiency of fish farming is possible only if there are proper central resources as well as extension facilities backed by research units and professional staff.

References

See references numbered 10, 79, 107, 174.

1.3.9 The effect of measures against fish diseases on the economics of fish culture

The problem of fish diseases and parasites was always significant in all fish culture activities, but in recent times it has become even more important, so that it is almost impossible to discuss the economic efficiency of fish farming without taking it into consideration. The development of fish diseases and parasite infestations is connected most of all with the trend toward more intensive forms of fish culture, in which fish are reared at high stocking densities and on a large scale (Webber and Riordan, 1976).

The problem of fish diseases has also been raised in connexion with insurance in fish culture (Secretan, 1979; Macfarlane and Varley, 1979).

In view of the above it seems paradoxical, that although there are plenty of papers dealing with the assessment of losses due to fish diseases (e.g., Macfarlane and Varley, 1976), there are almost no papers dealing with the economic effectiveness of measures undertaken against fish diseases.

Kalnibolockii (1976) has analysed the effects of fish disease prevention in fish farms of the so-called North-West Economic Region of the USSR in 1973. Prevention against a mass infestation of fry with *Philometra* (philometroidosis) in ponds of the Vielikolukskii combine saved some 1.2 million fish fry. Economic calculation proved that as a result a profit of 4.7 rubles was obtained per 1 ruble of expenditure on preventive measures. The fish farms under study obtained an additional 0.5 million market fish just by saving in the stocking material.

Veterinary assistance in the region under study resulted in increasing the fish production by about 250 kg/ha, i.e., by 30%. According to Kalnibolockii (1976) this improved the rentability of fish farms and the overall economic effect of measures against fish diseases in this region amounted to 205 000 rubles in 1973. Calculations showed that fry saved by these measures allowed an increase in market fish production by 770 000 kg. In order to obtain the same production of market fish it would be necessary to construct 1 100 ha of ponds, and the cost of investments would be 4.7 million rubles. Which represents the real value of savings resulting from proper veterinary services.

The above economic calculation is based on a substitutive method, and hence may raise some doubts. Nevertheless, it points to the significance of measures undertaken in order to prevent fish diseases, and to their effect on the economic effectiveness of fish culture. Unfortunately, this effect is still underestimated.

As in the case of fish selection, practical introduction of these measures requires the existence of properly developed network extension facilities.

References

See references numbered 61, 93, 127, 168.

1.3.10 The effect of mechanization on the economics of fish culture

Mechanization, especially of the most labour-intensive production processes in fish culture, is always connected with a considerable increase in investment and energy requirements but, on the other hand, it has significant production effects, yielding a considerable decrease in labour requirements and (as a rule) also a decrease in total operating costs.

In the case of large pond complexes mechanization becomes especially important due to the fact that on such complexes several production activities are extremely labour-consuming (Khristian and Grobokopatel, 1975). For instance mechanization of production on a 315 ha pond decreased labour requirements to 1/7th as regards the use of 1 ton of feeds, i.e., from 3.5 man-hours to 0.5 man-hours, while at the same time financial inputs decreased 1.4 times. Mechanization of catches increased the efficiency of labour about threefold (Khristian and Grobokopatel, 1975).

Based on certain studies Zapertova (1975) concluded that mechanization of the two most labour-intensive activities (i.e., fish feeding and fish catches,) increases the efficiency of labour by 12-20%.

Murin (1965) has made an attempt to assess the economic effectiveness of mechanization in Ukrainian pond farms in 1964. He used labour efficiency as the measure of its effectiveness. Dividing the fish farms described by this author into two groups, one with catch per fisherman higher than the average for all farms, and the other with catch per fisherman lower than the average, the following table of average values for the two groups is obtained (Table 54).

Table 54

	I group	II group	I/II in %
Value of fish catch/fisherman/rubles	4 981	3 052	163
Area (ha/fisherman)	14.1	26.6	53
Fixed capital/fisherman/rubles/technical devices	2.6	1.7	153
Electricity (1 000 kWh/h fisherman/year)	2.5	1.0	250

Based on Murin (1965)

Although the author does not make any further economic analysis, values presented in the above table clearly illustrate the effect of mechanization on fish culture economics.

According to Shabalín (1975) mechanization of fish catches in ponds, based on the use of net containers, shortened the duration of catch 3-4 times, with a simultaneous decrease of costs by 4.5 times compared to commonly used methods.

Independent of the mechanization in its broad sense, the improvement and introduction of fish culture equipment can often constitute one of the significant elements affecting the economics of fish culture. This effect may become apparent through:

- an improvement of production process resulting in an increased output,
- a decrease in necessary investment,
- a decrease of operating costs.

The above can be illustrated by an example given by Triamkin (1975). It appeared that by using a monk made of plastic (i.e., plastic pipes of proper diameter) instead of a traditional concrete one, the costs of this device decreased by 44%, while labour requirements for the installation of the monk decreased 3.5 times and the operating costs connected with its running decreased by 45%.

Bardach (1978) points out that some attention should be given to the importance of pond shape on the use of mechanization in catching; hence a combination of benefits might possibly be achieved if one were to consider both pond shape and the scope for mechanization.

References

See references numbered 66, 105, 130.

1.3.11 The effect of maintenance and improvement of ponds on the economics of fish culture

Proper maintenance of ponds and their improvement also affect the economics of fish culture. This effect is characterized by two aspects: (1) it allows for more intensive fish culture in improved ponds, and hence for farming characterized by higher economic efficiency, and (2) it allows for improving old ponds with lower expenditures than would be used for construction of new ponds, and hence for increased fish culture efficiency.

Shang (1976) presents an example of different economic efficiency of fish culture in Indonesia in three different variants of monoculture (Table 55).

Table 55

	Existing pond extensive	Improved pond intensive	New pond intensive
Improvement or construction costs in Rp		80 000	600 000
Operating cost in Rp	103 000	245 070	307 470
Profit in Rp	17 000	104 930	42 530
Rate of return on investment, %	-	131	9
Rate of return on operating costs, %	16	43	14
Cost/kg	343	245	308

Based on Shang (1976)

As is seen, the highest economic efficiency of fish culture was noted in the case of improved ponds (higher than in old and new ones). The same situation was noted in the case of new and improved ponds in polyculture (Shang, 1976).

The significant effect of maintenance and improvement of ponds can be indirectly illustrated by examples of production and economic results obtained in ponds and pond complexes of different technical quality. Murin (1974) presents production indices for drainable and undrainable ponds of the Ukraine in 1973 (Table 56).

Murin and Grobokopatel (1968) and Grobokopatel (1976) support the statement that pond reconstruction constitutes an important element in increasing fish culture efficiency, as illustrated by Tables 3 and 4.

However, it should be pointed out, that apart from Shang, all authors discuss the problem of pond draining without taking into account significant differences noted between the efficiency of production in drainable and undrainable ponds. According to Chizhik *et al.* (1973) natural productivity of drainable ponds is 30-33% higher than in undrainable ponds. Thus, further improvement of ponds, leading toward making the ponds drainable, will increase the efficiency of fish culture still further.

Table 56

Production indices	Drainable ponds	Undrainable ponds
Stocking rate indiv./ha	5 781.0	3 410
Survival rate, %	65.3	44.9
Individual fish weight, g	309.0	270.0
Number of fry/100 kg of market fish yield	496.0	824.0
Production, kg/ha	1 223.0	538.0

Based on Murin (1974)

Another possibility for increasing the efficiency of fish culture can be seen from analysing the difference between pond area and water surface used for fish production. Improvement of ponds aimed at increasing the latter area, which in some cases is as low as 50% of total pond area (Szamborski, 1968) would undoubtedly increase the effectiveness of fish production.

It should be emphasized that, apart from Shang (1976), there are really no papers dealing with the effect of improvement on the economics of fish culture, and that this factor has never been analysed from an economic point of view. This seems rather surprising, the more so since improvement of ponds is obviously not restricted to the above examples. For instance, Rotovskaia (1968) found that merely loosening the bottom of rearing ponds for 2-8 days after the ponds have been filled with water increases the production of fry by 26.5-37.7%. It seems it is high time that these factors were taken into account.

References

See references numbered 21, 53, 108, 109, 123, 132, 149.

1.3.12 The effect of expenditures on the economics of fish culture

Assessment of the effect of expenditures on the economic efficiency of fish culture constitutes an essential part of every economic calculation. However, in view of the existing literature, it seems appropriate to regard this effect as an intensification measure and to discuss separately the general effects of expenditures on the economics of fish culture.

The approach, of analysing various production and economic indices in relation to different operating or investment costs (capital) is broadly used in Soviet literature. This results from the opinion that at present the level of expenditure, in particular of operating costs, constitutes one of the best indices of the intensity of production, usefully separating its two basic forms, i.e., extensive and intensive fish culture.

Murin and Grobokopatel, (1968) compared pond fish farms on the basis of operating costs, as follows (Table 57):

Table 57

Average operating costs rubles/ha	Production kg/ha	Unit cost of production rubles/kg
116	123	0.94
305	389	0.78
721	1 095	0.66

According to Murin and Grobokopatel (1968)

The close connexion between production and economic results on the one hand, and expenditures on the other, is clearly visible. However, it should be pointed out that the level of decrease in unit cost of production is lower than the increase in expenditure and production. In reality when expenditures exceed a certain, defined level, their increase is usually connected with increasing unit cost of production, independent of the increase in other economic and production indices.

A situation such as that presented in the above table is usually connected with a low intensity of fish culture in general, as evidenced also by a rather low fish catch per ha.

Low fish production in the above example is, in turn, connected with capital costs per unit area, as illustrated by Table 58, based on data presented by the above cited authors.

Table 58

Group of farms with production kg/ha	Capital costs per 1 ha of market fish ponds	Kg of production per 1 000 rubles of capital costs
up to 100	824	161
200-400	1 298	252
400-800	1 757	380
over 800	2 122	582

ists in production and economic results of fish culture is unargued production with increasing capital costs, together with an capital investment, shows that this situation is typical for fish ofies of further intensification are still wide open.

The effect of increasing capital costs on the level of intensity of pond culture who

Table 59

Operating costs (rubles/ha)	up to 300	300-600	600-900	over 900
costs (rubles/ha)	202	425	666	1 306
%	100	210	330	646
a)	326	759	935	1 531
%	100	233	287	470
ion (rubles/100 ha)	63.04	63.30	61.07	65.58
%	100	100.4	96.9	104.0
of production (rubles/l ruble operating costs)	0.9	1.2	1.3	1.4
%	100	133	144	156
Capital cost (rubles/ha) of pond	748	878	885	2 567
%	100	117	118	343
Kg of production/1 000 rubles of cost	280	520	750	470
%	100	186	268	168

Based on data by Galasun and Grobokopatel (1973)

The trends are clear since apart from the obvious relationship between production and economic results on the one hand, and capital costs and (especially) operating costs on the other, this table also shows that the results increase at a much slower rate than the expenditures. At a certain level of expenditure the benefits start to decrease. It should be underlined that this table represents a different type of fish culture to the previous one, as proved by the higher level of production. Consequently, the tendency of certain indices to decrease along with increasing expenditure is more clear here than in the previous example.

Korolev (1975) analysed annual reports from 93 fish farms in 1960-1973, using the level of operating costs as the criterion of the intensity of fish culture. His results are presented in Table 60 (data from 24 fish farms).

Table 60

	Level of operating costs/l ha of market fish ponds in thousand rubles			
	up to 0.5	0.5-0.75	0.75-1.0	over 1.0
Fish catch in rubles/ha	650	980	1 340	1 930
Profit/ha in rubles	95	112	216	342
Cost of producing 100 kg fish in rubles	60.46	71.59	63.88	64.04
Value of production in rubles/l ruble of operating costs	1.24	1.18	1.28	1.28

Based on Korolev (1975)

The positive effect of an increasing level of operating costs on indices of fish culture is quite evident, notwithstanding a slight increase in costs.

The same effect is also noted in Polish materials (Materials of the sented in Table 61.

Table 61

	Operating costs in 1 000 z1/ha			
	5-10	10-15	15-20	over
Average operating costs in 1 000 z1/ha	7.7	12.3	17.0	23.2
Fish catch in kg/ha	292	494	711	841
Rentability of operating costs in %	-	6.5	27.6	40.1
Operating costs in z1/kg of fish	26.4	24.9	23.9	27.6

More detailed preliminary analysis of the same 24 farms in 1972/73, using linear correlation methods, showed that there is an almost functional dependence between the level of operating costs in these farms and the income per 1 ha. The correlation coefficient (r) amounted to 0.941, while the value of 0.515 would be sufficient for significant correlation at the level of significance $p = 0.01$. A similar dependence exists between the level of operating costs per 1 ha and the fish catch in kg/ha ($r = 0.708$), as well as between the level of operating costs per 1 ha and the level of capital costs per 1 ha ($r = 0.708$).

Significant dependence was found also between the level of capital costs per 1 ha and income per ha ($r = 0.523$).

It may be stated generally, that analysis of particular production of economic indices in relation to expenditures can be valuable and meaningful even if the expenditures are aggregated and treated as a whole. Any deviation from the average for a given situation determines the direction of further economic analysis, explaining the cause of observed anomalies, and indicating appropriate measures to improve an unsatisfactory situation or to exploit a satisfactory one. In this respect a special role is played by correlation and regression analysis (Gordon and Erman, 1974 a, b; Worniallo, 1970 a, b; Worniallo, 1973 a, b; Kazun and Worniallo, 1973).

References

See references numbered 44, 50, 51, 70, 78, 109, 176, 177, 178, 179.

2. GENERAL OUTLINE OF FEASIBLE ECONOMIC ANALYSIS OF FISH CULTURE - CONCLUDING REMARKS

The material and comments clearly show that so far there is no universal method for economic analysis of fish culture, especially if it has to be used for comparing economic efficiency of fish farming activities. This mostly results, from the fact that we still do not have any method of economic analysis which would fully reflect the characteristics of fish culture. No matter how paradoxical this statement may seem it is certainly true. Furthermore, we still do not generally possess sufficient information for making economic analyses of fish culture, especially such as can be used for comparisons. In the present study an attempt was made at a preliminary analysis of materials collected by the Working Party, and of data available from the literature on the subject. This analysis showed that enormous difficulties are encountered even during a tentative effort to illustrate with specific examples the most feasible scheme for an economic appraisal of fish culture. Of course it is always possible to make a comparative analysis of trout and carp culture, fish culture in cages, raceways, tanks, etc. However, the result of such analyses apart from whether they are based on some assumed, theoretical parameters, or on real data gathered from the existing farms will have only relative value if it does not take into account the characteristics of fish culture and its general and specific role.

The above statements do not negate the practical values of such incomplete analyses, provided we remember that their results are relative. Because of this, the incorporation of natural and production indices into the analysis becomes significant. Such indices can often explain economically complex situations, as illustrated by the effect of the size of production units on economic efficiency of fish culture discussed in section 1.1. Part II.

A general simplified outline of feasible economic analysis (especially if used for comparisons between different forms of fish culture) is presented below, together with the range of information that should be gathered for such analysis:

(i) The introductory part, preceding the actual economic analysis, should contain all available information on natural factors determining the situation in which fish culture is operating, be it by enterprise, region, or on whatever scale. For comparative purposes it is most appropriate to distinguish here all "common" factors, which are integral to fish culture independently of the situation, as well as specific factors, which apply only to the given situation. For instance, common factors embrace climatic and hydrological conditions, duration of the growing season, size of production units, etc. Whereas examples of specific factors might include frequent wind storms in a given area, catastrophic water deficits, or the opposite - frequent floods, etc. In numerous cases specific factors will be connected with specific roles played by fish culture in the given situation. It is worth noting too that at present these factors are rarely, if ever, included in economic analyses of fish culture, except in the form of explanatory remarks.

(ii) The introductory part (and the actual analysis) should contain information on all available economic factors determining the given situation in which fish culture is operating, (e.g., enterprise, group of enterprises, region, etc.) Similarly as in case of natural factors, we should try to distinguish here both common and specific economic factors. The most common economic factor of this type is, any general policy toward fish culture. Policy toward fish culture is usually connected with the problem of obtaining credits, level of interest on loans, tax reduction, etc., i.e., those elements which may significantly affect the structure of costs and profitability of production. It is also connected with unrecognized problems regarding the possibilities of obtaining expert advice and necessary training. Information of this type embraces the main problem of resource availability, i.e., capital, material, energy, labour, and land resources. It should be explained that as regards capital resources, weight should be given to the availability of initial investment capital, with special attention paid to constructions, whereas in the case of material resources weight should be given to feeds, stocking material and fertilizers, and in the case of energy resources to fuel.

All these elements are, or should be, included in economic analysis. Nevertheless, they frequently do not explain the significant differences noted in this respect when the same form of fish culture is practised in different enterprises, regions, etc.

Particularly valuable economic information which should also be included in this part are the resource costs especially of material resources and the prices of the final product - market fish. These values are frequently assigned by calculation of particular items in economic accounting, but they should also be plainly presented in this part of the analysis. The introductory part should also embrace at least general information on market demand for fish culture products and on prices of other land-based animal food products.

Apart from such common economic information, which is extremely valuable for making proper comparisons, the introductory part should also present all specific economic factors affecting given enterprises and their operations. For example, lack of man-power due to better working or financial conditions in some near-by factory would represent a significant factor affecting the efficiency of a given enterprise. In most cases, however, specific economic factors are connected with the roles played by fish culture.

(iii) The introductory part preceding the actual economic analysis should also contain all relevant information, which usually determines good or bad general conditions of production. For instance in the case of common factors, we have, the arrangement of ponds in fish farms, their technical state (e.g. linked to pondage), pond depth etc. Specific factors mostly embrace production factors connected with various specific roles played by fish culture, such as the necessity of defined water management, water pollution, etc.

Hence, the introductory part constitutes a specific "register" for the given unit of fish culture, which is indispensable for feasible economic analysis of its efficiency.

(iv) Cost accounting constitutes a basic element of economic analysis and, as currently applied to fish culture, is based on varying methods of cost arrangement and on the accuracy of cost items. This creates significant difficulties in the interpretation of results, especially in the case of comparisons and frequently does not allow unequivocal conclusions. Although the method of cost accounting in a fish farm is dependent on the farmer, or on the given situation, a simple and basic rule can be given, based on the recognition that some items of costs are essential, independent of the form and situation.

As regards capital investment (capital costs) essentially three items are recognizable, namely "cost of pond construction" (or other holding facility), "cost of mechanical equipment" (machines, transport equipment), and "other capital costs".

With respect to operating costs the following are essential: "feeds", "stocking material", "fertilizer", "power" (electricity, fuel), "labour", "depreciation", "interest", "rent", and "other operating costs".

It should be underlined that the above constitute an indispensable minimum of items, which should be represented separately in any cost accounts. As seen from an analysis of FAO materials, the literature, and field studies, these items are most frequently used in cost accounting. Items which can be expressed in physical units, such as "feeds", "stocking material", "fertilizer", "labour", and "power" should also be expressed as such.

(v) In the output part of economic analysis, which consists of comparing costs and effects, three types of indices should be used, as in the introductory part. This follows from the fact that cost items can and should be expressed both in natural and financial units. Similarly production must be expressed not only in financial units (as income,) but in physical units (kg). In expressing operating costs in physical units, attention should be paid to stocking material, represented both in the number of individuals and in kilogrammes. In the case of labour costs it is best to use the number of employees if managerial staff are included, or, if not, to specify that the numbers refer to those employed directly in production.

Therefore, apart from the various economic indices which can be obtained from the above items, especially capital and operating costs versus income and production, several natural and physical indices can be derived, some of which have been used in the present study. In the case of certain specific factors, these indices would also be of a specific nature, and hence their use for comparison might be significantly restricted.

The detailed application and interpretation of such indices, depend on the needs of those who make the analysis, and on its aims, and thus should be the subject of a separate study.

To summarize, it should be emphasized that incorporating natural and production indices into the economic analysis of fish culture offers possibilities for integrating economic analyses with modern methods is of energy accounting in fish culture.

PART III - REFERENCES

A. PUBLISHED PAPERS

1. Allen G.H. and B. Hephher, Recycling of wastes through aquaculture and constraints to wider application. In Advances in aquaculture. Papers presented at the FAO Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books for FAO, pp. 478-86
2. Altukhov, K.A., Primenenie mineral nykh udobrenii v prudakh rybkhozov zapadnykh oblastei 1976 Ukrainy (The use of mineral fertilizers in ponds of the Western Ukraine). Rybn. Khoz., Kiev, 23:32-40
3. Anisnev, V., Ulochsit' ispol' zovanie prudovogo fonda kolkhovov i sovkhovov (How to improve the utilization of ponds in state and cooperative agricultural farms). Rybovod. Rybolov., 5:2-3
4. Ananiasis, C.J., Fish farming development prospects in Greece. Fish Farming Int., 4(3):16-7 1977
5. Andrzejewski, R. et al., Problematyka ekologiczna w programie "Czlowiek i srodowisko" 1973 (Ecological problems in the programme "Man and Environment"). Kosmos(Ser.A), 6:635-40
6. Aquaculture Development and Coordination Programme (ADCP), Report of the Regional Workshop on aquaculture planning in Asia. Bangkok, Thailand, 1-17 October, 1975. Rome, FAO/UNDP, ADCP/REP/76/2:154 p.
7. Avault, J.W., Economics of various pond sizes. Commer.Fish Farmer World Aquacult.News, 1974 1(2):49
8. Babaian, K. and L. Gordon, Sovremennoie sostoiianie i perspektivy razvitiia prudovogo rybovodstva SSSR (Present state and perspectives for the development of pond fish culture in the USSR). Moscow, Izd. Fishchevaia Promyshlennost, 98 p.
9. Bakhatina, V., Kak uvelichit' bentos v nagulnykh prudakh (How to increase bottom fauna in ponds). Rybovod.Rybolov., 4:9
10. Bakos, J., Crossbreeding Hungarian races of common carp to develop more productive hybrids. 1979 In Advances in aquaculture. Papers presented at the FAO Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books Ltd., for FAO, pp. 633-5
11. Balshova, M.N., P.T. Galasun and N.N. Kharitonova, K kharakteristike pishchevoi cennosti karpov razlichnykh vesovykh grupp (Characteristic of nutritive value of carp in different weight classes). Rybn.Khoz., Kiev, 20:22-6
12. Bartling, G., Binnenfischerei. Jahresber.Dtsch.Fischwirtsch., (1974-75):48-54 1975
13. Bautrel, B., Zagospodarowanie wyrobisk koncowych w kamienilomach (Recultivation of old stone-pits). Pr.Nauk.Osrod.Bad.Prognost.Politech.Wroclaw.(Ser.Konf.5), 7:109-12
14. Beliaev, V., Trekhletnii oborot v rybkombinate "L'uban" (3-year cycle in Liuban" fish farm). 1976 Rybovod.Rybolov., 3:3-4

15. Berge, L., A proposal for economic investigations of fish farms with special reference to bookkeeping and financial analysis. In Advances in aquaculture. Papers presented at the FAO Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books Ltd., for FAO, pp. 239-46
16. Bezdolnyi, N., Prud polnaia chasha (Pond - full of richness). Rybovod.Rybolov., 4:6-7 1971
17. Brown, E.E., Fish production costs using alternative systems and the economic advantages of double-cropping. In Advances in aquaculture. Papers presented at the FAO Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books Ltd., for FAO, pp. 235-9
18. Carandang, F.L. and L.B. Darrah, Bangus production costs. Manila, National Food Agriculture Council, Department of Agriculture and Natural Resources, 18 p.
19. Chizhik, A.K., Rybovodstvo i irrigacia (Fish culture and irrigation). Moscow, Izd. Kolos, 1970 127 p.
20. Chizhik, A.K. and V.D. Chumachenko, Vliianie glubiny prudov na rybovodnye pokazateli (The effect of pond depth on the results of fish production). Rybn.Khoz., 2:22-4
21. Chizhik, A.K., V.D. Chumachenko and E.I. Shchekha, Osennee zapol'nienie i zarybienie prudov kak metod povysheniia ryboproduktivnosti (Autumn filling and stocking as a method of increasing fish production in ponds). Rybn.Khoz., 1:11-3
22. Chuprov, K., Rybolovetskie kolkhozy vyrashchivaiut rybu (Fishery collective farms culture the fish). Rybovod.Rybolov., 5:5
23. Collins, R.A. and M.N. Dalmacio, Comparative economics of aquaculture in cages, raceways and enclosures. In Advances in aquaculture. Papers presented at the FAO Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books Ltd., for FAO, pp. 472-7
24. Cygankov, I.V. and I.N. Poleguyev, Osennee zarybienie nagul'nykh prudov kak metod zimovki posadochnogo materiala karpa (Autumn stocking of ponds as a method of wintering carp stocking material). Vopr.Rybn.Khoz.Bel., 7:45-50
25. Cygankov, I. et al., Chto daet udobrenie prudov silvinitom i ammiachnoi vodoi (The results of fertilization with sylvinit and ammonia water). Rybovod.Rybolov., 3:11-2
26. Dabrowski, B., Economic analysis of inland fisheries. EIFAC/Econ/WP 72 1972
27. Day, C., Special attention is needed to exploit Africa's fish potential. Fish Farming Int., 4(1):36-7 1977
28. Demchenko, F.I., V zashchitu krupnykh nagulnykh prudov (In defence of large market fish ponds). Rybovod.Rybolov., 5 1974
29. Demchenko, F.I. and G.I. Shpet, Rol' kompleksnogo udobreniia v povyshenii estatannoi ryboproduktivnosti prudov (The role of complex fertilization in increasing natural productivity of fish ponds). Rybn.Khoz., 5:22-4 1973
30. Demchenko, F.I. and G.I. Shpat, Povyseniie produktivnosti prudov Ukrainy za poslednia 20 let (Increase of productivity in Ukrainian ponds in the recent 20 years). Rybn.Khoz., Kiev, 24:9-14 1977

31. Donskii, N., Kompleksnoe ispol'zovanie meliorativnykh sistem (Complex utilization of drainage system). Rybovod.Rybolov., 2:4-5
32. Dubel, K., Jak eksploatowac surowce nie niszczac srodowiska (Exploitation of resources without environment destruction). Aura, 11:7-9
33. Dudzinski, L. and W. Orlowski, Wielofunkcyjne wykorzystanie malych zbiornikow wodnych. Naczelna Organizacja Techniczna Stowarzyszenie Inzynierow i Technikow Wodnych i Melioracyjnych. In Kryteria lokalizacji i wykorzystania malych zbiornikow wodnych (Multipurpose utilization of small water bodies. Main Technical Organization Association of Engineering and Technical Criteria for the localization and utilization of small water bodies). Wroclaw, International Scientific Technical Conference, pp. 30-40
34. Dukhnovskii, M.K., Ekonomichaskaia effektivnost' vyrashchivaniia rastitel'nojadykh ryb v prudakh (Economic efficiency of plant feeding fish production in ponds). Rybn. Khoz., Kiev, 11:101-7
35. _____, Ekonomichaskaia effektivnost' vyrashchivaniia rastitel'nojadykh ryb v Doneckom rybkombinate (Economic efficiency of plant feeding fishes in Don pond combine). Rybn. Khoz., Kiev, 14:129-31
36. _____, Naobkhdimo zvano proizvodstva (Necessary chain of production). Rybovod. Rybolov., 3:6-7
37. Duvigneaud, P., Biosfera jako srodowisko czlowieka. Warsaw, PWRiL 1975
38. Dziewonski, Z., Retencja wodna jako czynniki ochrony srodowiska (Water retention as a factor of environment protection). Aura, 5:7-9
39. Edwardson, W., Energy demands of aquaculture - a worldwide survey. Fish Farming Int., 3(4) 1976
40. Eleonskii, A.N., Produkcii rybovodstvo (Pond fish culture). Moscow, Pishchepromizdat 1946
41. FAO, Consultative Group on International Agricultural Research, Technical Advisory Committee, 1973 Report of the TAC Working Group on aquaculture. (Agenda Item 4) Spoleto meeting. Paper prepared for the Consultative Group on International Agricultural Research, TAC Seventh meeting, Roma, 4-8 February 1974. Rome, FAO, DDDR:1AR 73/75:25 p (mimeo)
41. FAO/UNDP Aquaculture Development and Coordination Programme, Aquaculture planning in Asia: bis 1976 report of the Regional Workshop on Aquaculture Planning in Asia, Bangkok, Thailand, 1-17 October 1975. Rome, ADCP/REP/76/2, 154 p.
42. Fatoeva, L., Ispol'zovanie basseiny (Lat's usa tha tanks). Rybovod.Rybolov., 5:9-10 1976
43. Foster, T.H. and I.E. Waldrop, Cost-size relationships in the production of pond raised catfish for food. Bull. Miss. State Univ. Agric. For. Exp. Stn., (792):69 p. 1972
44. Galasun, P.T. and M.G. Grobokopatal, Intensifikatsiia prудovogo rybovodstva - glavnyi put' uvelicheniia proizvodstva prудovoi ryby (Intensification of pond fish farming - main methods of increasing pond fish production). Rybn. Khoz., Kiev, 17:3-9 1973
45. Galasun, P.T., N.N. Kharitonova and N.N. Balashova, K kharakteristike pishchevoi cennosti karpov razlichnykh vesovykh grupp (Characteristic of nutritive value of carp in different weight classes). Rybn. Khoz., Kiev, 13:9-12 1971
46. Galasun, P.T. and N.N. Kharitonova, Sovershanstvovanie metoda kompleksnoi intensifikatsii prудovogo rybovodstva (Improvement of methods of complex intensification of pond fish culture). Rybn. Khoz., 10:24-8 1975

47. Garin, A., Zimovka molodi ryb v basseina (Wintering of fish fry in tanks). Rybovod.Rybolov., 1976 9:10-1
48. Gnatiuk, E. and L. Sigal, Samaia deshevaia ryba vyrashchivaet'sia v Belorussii (The cheapest fish is produced in Belorussia). Rybovod.Rybolov., 1:6-7
49. Gordon, L. and L. Erman, Osnovnye tendentsii razvitiia tovarnogo rybovodstva (Basic trends in the development of market fish production). Rybovod.Rybolov., 4:3-5
50. _____, Opyt primeneniia korrelatsionnogo analiza dlia ocenki i planirovaniia deiatel'nosti prudoovykh khoziaistv (A study on the use of correlation analysis for the assessment and planning of the activities in pond fishery). Rybn.Khoz., 1974 4:76-8
51. _____, Korrelatsionnyi analiz nekotorykh pokazatelei effektivnosti raboty prudoovykh khoziaistv (An attempt to use correlation analysis for the assessment and planning of pond fish farms). Rybn.Khoz., 5:78-82
52. Gordon, L. et al., Dvukhletnii ili trekhletnii oborot? (Two- or three-year cycle?). Rybovod. Rybolov., 1975 4:5-6
53. Grobokopatel, M.G., O nekotorykh merakh povysheniia ekonomicheskoi effektivnosti raboty prudoovykh khoziaistv (Some measures of increasing economic efficiency of pond fish farms). Rybn.Khoz., Kiev, 23:3-7
54. Hickling, C.F., Fish culture. London, Faber and Faber, 295 p. 1962
55. Hofman, L. and A. Kortylewska, Ekonomiczne problemy gospodarki wodnej Polski (Economic problems of water management in Poland). Warsaw, PWN
56. Huet, M., Textbook of fish culture: breeding and cultivation of fish. London, Fishing News Books Ltd., 436 p., 4th ed. 1972
57. IPPC, Report on studies on the economics of aquaculture in the Indo-Pacific region. Proc. IPFC, 1975 16(1-2):98-105
58. Isaiev, A., Rezervy dolzhny byt' privedeny v deistvie (Reserves should be used). Rybovod. Rybolov., 1975 4:3-4
59. Jermakowicz, W., Glowne zalozenia polityki ochrony srodowiska (Main principles of policy for environment protection). Ekonomista, 1:143-57
60. Kacza, A., Analiza wybranych czynnikow warunkujacych wysokie wyniki produkcyjne w Zakladzie Psary Panstowowych Gospodarstw Rybackich (Analysis of selected factors determining high production results in Psary State Fish Farm). M.Sci. degree, Olstyn (MS) 1978
61. Kalnibolockii, A.A., Osnovnye metodiki opredeleniia ushcherba, prichiniaemogo rybnomu khoziaistvu bolezniami ryb (Methods for determination of the damage to fishery management brought about by fish diseases). Izv.Gos.Nauchno-Issled.Inst.Ozern. Rechn.Rybn.Khoz., 105:127-9
62. Kanaev, A., Dostizhenia nauki v oblasti ikhtiopatologii i ikh vnedrenie v proizvodstvo (Results of studies in the field of ichthyopathology and their introduction into fish farming). Rybovod.Rybolov., 5:13-4
63. Kanidev, A.N. and E.A. Gamygin, Increasing the efficiency of full value pelleted feeds for rainbow trout by substituting vegetable for animal protein. Tr.Vses.Nauchno-Issled.Inst.Prudov.Khoz., 24:33-55

64. Kaniszewski, S. and J. Rumpel, Problemy wody w intensywniej produkcji warzyw (Problem of water in intensive horticulture). In Materials of Scientific and Technical Conference on Rational Water Management in Intensive Plant Production. Warsaw, NOT SITR, SITWM, pp. 59-69
1976
65. Kurovskii, E.A., Rasshchot optimal'nykh plotnostei posadki ryby dlia vyrostenykh i nagul'nykh prudov (Calculation of optimal stocking rate for rearing and fattening fish in ponds). Rybn.Khoz., 12:17-20
1977
66. Khristian, A. and M.G. Grobokopatel, Rezervy bolshikh prudov (Reserves of big ponds). Rybovod.Rybolov., 5:7
1975
67. Klimenko, R., Vykhod - 75% (Result - 75%). Rybovod.Rybolov., 5:10-1
1976
68. Kolkin, S.F., Osobennosti razvitiia prudovogo rybovodstva v Rostovskoi oblasti (Remarks on the development of pond culture in the Rostovska province). Rybn.Khoz., 3:19-21
1976
69. Korobko, V.I., Uroven' koncentracii i effektivnost' proizvodstva (Degree of concentration and the effectiveness of production). Rybn.Khoz., 5:73-5
1973
70. Korolev, A., Effektivnost' zaviesit ot intensifikacii (Effectiveness depends on the intensification). Rybovod.Rybolov., 3:4-5
1975a
71. _____, Voprosy ekonomiki kormleniia prudovoi ryby (Problems of the economics of pond fish feeding). Rybn.Khoz., 9:83-5
1975b
72. _____, Koncentraciia, specializaciia i kombinirovanie proizvodstva v prudovykh khozias'tvakh (Concentration, specialization and integration of production in pond farms). Rybn.Khoz., 1:64-6
1976
73. Kossakowski, G., Analiza produkcii karpia w jeziorze Maly G1l (Analysis of carp production in Maly G1l Lake). Gospod.Rybn., 9:9-11
1974
74. Kostiskov, V., O vliisnii vesa godovikov karpa na rybovodnye pokazateli (The effect of carp yearling weight on the results of fish production). Rybovod.Rybolov., 2:12
1975
75. Kozun, J., Efektivnost' gosudarstva pasz w karpiowym gospodarstwie stawowym (Effectiveness of feeds in carp pond farms). Olsztyn, IFI, Extension booklet
1970
76. _____, Ocena celowosci stosowanie 2- i 3-letniego systemu produkcii karpia w stawach (Estimation of carp production in ponds in 2-year and 3-year rearing system). Rocz.Nauk Roln.(Ser.H), 95(4):85-105
1973
77. _____, Charakterystyka wielkoscii obiektow stawowych i ich zlewni w Polsce (Characteristics of the size of pond complexes and their drainage area in Poland (in preparation))
1973
78. Kozun, J. and J. Worniallo, Badanie wplywu niekatorych czynnikow na produkcje karpia towarowego w systemie 2-letnim (Studies on the effect of some factors upon the production of marketable carp in a 2-year cycle). Rocz.Nauk Roln.(Ser.H), 95(4):107-16
1973
79. Krasavcev, J., Sovershenstvovat' organizaciu selekcionnogo-plemennogo dela v prudovom rybovodstvie (Improvement of selection in pond fish culture). Rybovod.Rybolov., 1:9-10
1975
80. Krupaer, V., Pond fish culture in Czechoslovakia. EIFAC Occas.Pap., (8):37 p.
1973

81. Kryzynek, J., Proba oplacalnosci indywidualnych gospodarstw stawowych (An attempt to define the profitability of individual pond fish farms). M.Sc. degree, Olsztyn (MS) 1971
82. Kucharz, J., Widmo pustyni (A desert phantom). Aura, 6:13-4 1974
82. Kurovskii, E.A., Rasshchot optimal'nykh pletnostei posadki ryby dlia vyrostnykh i nagul'nykh bis prudov (Calculation of optimal stocking rate for rearing and fattening fish ponds). Rybn.Khoz., 12:17-20 1977
83. Lebadeva, I., Chto dala polykultura (What did polyculture give). Rybovod.Rybolov., 3:10 1970
84. Lech, M. and M. Kisielewska, Psary w ostatnim roku planu 5-letniego (Psary State Farm in the last year of the 5-year plan). Gospod.Rybn., 6:12 1976
85. Lech, M. et al., Psary w ostatnim roku planu 5-letniego (Psary Fish Farm in the last year of the 5-year plan). Gospod.Rybn., 2:12 1976
86. Leopold, M., Polska Norma. Rybactwo stawowe. Nazwy i okreslenia (Polish norms. Pond fish farming. Terms and definitions). Warsaw 1976
87. Leopold, M. and J. Kozun, Ekonomiczne kryteria celowosci utrzymywania drobnych obiektow stawowych (Economic criteria of maintaining small pond complexes). Conf., Budejovice, Czechoslovakia 1974
88. Liszkowski, L., Efekty i kierunki rybackiego zagospodarowanie terenow bagienno-gyttiowiskowych (Effects and directions of fishery management in boggy areas). Post-graduate Workshop. Olsztyn Inland Fisheries Institute (mimeo) 1978
89. Lovell, T., Energy. Commer.Fish Farmer World Aquacult.News, 2(4):40-1 1976a
90. ———, Fish farming industry becomes a rich source of animal protein. Commer.Fish Farmer World Aquacult.News, 3(1):49-50 1976b
91. Luchenko, M., Sosredotochit 'vnimanie na nareshennykh zadachakh (Let's draw attention to unsolved problems). Rybovod.Rybolov., 2:1-2 1971
92. Lukowicz, M., von, Die Wirtschaftlichkeit der Haltung von Karpfen in Teichen. Fischwirt regeln. Fischwirt, 24(7) 1974
93. Macfarlane, I.S. and L.R. Varley, Risks, mortality and insurance on European trout farms. 1979 In Advances in aquaculture. Papers presented at the FAO Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books Ltd., for FAO, pp. 70-4
94. Mertyshev, F., Vazhnaiia gosudarstvennaia problema (An important management problem). Rybovod.Rybolov., 2:3 1970
95. ———, Prudovoie rybokhoziaistvo (Pond fish culture). Moscow, Izd. Vyssh. Shkola, 426 p. 1973
96. ———, Neobkhodim novyi podkhod k vedeniiu prudovogo rybnogo khoziaistva (Necessary new approach to pond fish farming). Rybovod.Rybolov., 2:2-3 1973
97. ———, Trebuetsia priniatie reshitel'nykh mer (Necessity of introducing effective measures). Rybovod.Rybolov., 4:2-3 1974
98. Maslov, E., Ryboproduktivnost' vyrostnykh prudov pri razlichnykh usloviakh vyrashchivaniia molodi karpa (Productivity of rearing ponds at different rearing conditions). Rybovod.Rybolov., 3:12-3 1973

99. Maslova, N., Ot chego zavisiat vykhod i kachestvo tovarnoi produkcii (On what depend the results and quality of commercial production). Rybovod.Rybolov., 2:12
100. McCoy, E.W. and J.L. Boutwell, Preparation of financial budget for fish production, catfish production in areas with level land and adequate ground water. Circ.Agric.Exp. Stn.Auburn Univ., (233)
101. Michaelis, T., Ob ocenke ekonomicheskoi effektivnosti ispolzovaniia kombikormov v tovarnom rybovodstvie (Assessment of economic effectiveness of the use of food mixtures in market fish production). Rybn.Khoz., 1:67-71
102. Michalik, S., Ochrona przyrody a rekreacja (Nature protection and recreation). Chron.Przyr. 1974 Ojczyzna, 30(11):7-13
103. Mikitei, M. and V. Polishchuk, Pribylnaia otrasl "kolchoza (Income of farms). Rybovod. 1976 Rybolov., 4:11-2
104. Moderski, J. and J. Szamborski, Analiza kosztow produkcji gospodarstw rejonowego oddzialu ZCP Ryb w Miliczu (Analysis of production costs in farms of the Milicz fish farms branch). Gospod.Rybn., 5:18-9
105. Murin, V.A., Ekonomicheskaiia ocenka effektivnosti mekhanizacii prudoogo rybovodstva (Economic assessment of the effectiveness of mechanization in pond farms). Rybn.Khoz., Kiev, 2:97-105
106. _____, Nasushchnye voprosy gosudarstvennogo prudoogo rybovodstva (Current problems of pond fish culture). Rybn.Khoz., 6:74-5
107. _____, Intensifikaciia rybnogo khoziaistva (Intensification of fish culture). Kiev, 1972 Izd. Urozhaj, 114 p.
108. _____, Optymalizaciia rybovodnykh processov (Optimization of fish production processes). 1974 Rybovod.Rybolov., 3:4-7
109. Murin, V.A. and M.G. Grobokopatel, Vysokii uroven "intensifikacii glavnoe uslovie rosta rentabil'nosti rybkhozov (High level of intensification - main condition for the increase of fish farm rentability). Rybn.Khoz., Kiev, 6:28-35
110. Neal, R.A., Alternatives in aquaculture development: consideration of extensive versus intensive methods. J.Fish.Res.Board Can., 30(12)Pt.2:2218-22
111. Opuszynski, K., Wykorzystanie ryb roslinozernych do zwalczania roslin wodnych (Utilization of phytophagous fishes for water weeds control). Wied.Ekol., 18(2):111-24
112. Osetrov, V., Problema zimovki molodi ryb budet "reshena (A solution to the problem of wintering young fishes). Rybovod.Rybolov., 2:14-5
113. Pancenko, S. and E. Porokhovskaia, Soveshchanie po kormleniu ryb, udobreniiu prudov (Meeting on fish feeding and pond fertilization). Rybovod.Rybolov., 2:9
114. Pavlov, P. and L. Glushchenko, Rybnoe khoziaistvo "Juzhnyi" (Juzhnyi fish farm). Rybovod. 1974 Rybolov., 5:4-5
115. Pazur, K., Data about commercial breeding in Yugoslavia. Rome, FAO, EIFAC 70/SC, 1/6 1970
116. Philippines, Bureau of Fisheries and Aquatic Resources, Swampland could support ponds in the Philippines. Fish Farming Int., 4(3):4

117. Pillay, T.V.R., The role of aquaculture in fishery development and management. J.Fish.Res.
1973 Board Can., 30(12)Pt.2:2202-17
118. Platek, R., Plusy i minusy melioracji (Advantages and disadvantages of drainage). Aura,
1977 3:13-4
119. Poliakov, G.D., Sravnienie effektivnosti ispol'zovaniia kormov prudovymi rybami i sel
kokhoziastvennymi zhivotnymi (Efficiency of feeding in fish and animal production).
1967 Tr.Sovetsk.Rybovod., 7:104-16
120. Prosiannyj V.S., Z.A. Makina and E.M. Francuzova, Ispo'zovanie vodoemov stochnykh vod
1965 sakharnykh zavodov dlia vyrashchivaniia ryby (The use of sugar factory wastes
for fish production). Rybn.Khoz., Kiev, 2:21-5
121. Rabenall, M.R. and Y.C. Shang, The economics of various management techniques for pond fish
1979 culture of finfish. In Advances in aquaculture. Papers presented at the FAO
Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited
by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books Ltd., for
FAO, pp. 224-35
122. Rappaport, U., S. Sarig and Y. Bajerano, Observations on the use of organic fertilizers in
1977 intensive fish farming at the Ginosar Station in 1976. Bamidgeh, 29(2):57-70
123. Rotovskaia, V.S., Vliianie rykhlenia lozha vyrostnykh prudov na usilenie donnoy kormovoy
1968 bazy (The effect of loosening the bottom in rearing ponds on the development of
bottom food resources). Rybn.Khoz., Kiev, 6:75-80
124. Rychlicki, Z., Produkcja w stawach plytszych i glebzych (Production in shallower and deeper
1971 ponds). Gospod.Rybn., 4:6
125. Sauberlich, E. and C. Bauer, Steigerung der Hektarertrage durch Belüftung des Teichwassers.
1975 Z.Binnenfisch., D.D.R., 22(10):300-5
126. Schroeder, G.L., Factors affecting feed conversion ratio in fish ponds. Bamidgeh, 25(4):
1973 104-13
127. Secretan, P.A.D., Insurance and risk management for the aquaculture industry. In Advances
1979 in aquaculture. Papers presented at the FAO Technical Conference on aquaculture,
Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill.
Farnham, Surrey, Fishing News Books Ltd., for FAO, pp. 63-70
128. Semkow, J., Niektore problemy ochrony srodowiska (Some problems of environment protection).
1974 Gospod.Plan., 29(9):583-7
129. Sergeev, J.S., Ob ekologicheskoi effektivnosti vyrashchivaniia ryby (Ecologic effectiveness
1977 of fish culture). Rybn.Khoz., 1:20-3
130. Shabalin, S.F., Puti povysheniia ekonomicheskoi effektivnosti prudovogo rybovodstva (Methods
1975 of increasing the efficiency of pond culture). Rybn.Khoz., 4:5-9
131. Shang, Y.C., Comparison of the economic potential of aquaculture, land and animal husbandry
1973 and ocean fisheries: the case of Taiwan. Aquaculture, 2:187-95
132. _____, Indonesian milkfish farming - an economic evaluation. Fish Farming Int.,
1976 3(4):42-4
133. Shevrin, M., Kompleksnoe ispol'zovanie vodnykh i zemel'nykh resursov (Complex use of water
1976 and land resources). Rybovod.Rybolov., 1:9-10

134. Shpet, G.I., Razmery pruda i ego produktivnost (Size of ponds and their productivity).
1961 Rybn.Khoz., 5:31-3
135. _____, Svravnitel' naia effektivnost' ispol' zovaniia edinicy ploshchadi dlia rybovodstva i pod sel' skokhoziaistvennyie kul'tury (Efficiency of land utilization in fish and animal production). Gidrobiol.Zh., 8(3):62-8
136. Shpet, G.I. and L. Bakunenko, Ryboproduktivnost' bol'shikh i mal'kikh prudov (Fish production in big and small ponds). Rybodov.Rybolov., 6:14-5
137. Shpet, G.I. et al., O rashkode vody na edinicu vyrashchivaemoy ryboprodukcii (Use of water per unit of fish production). Rybn.Khoz., Kiev, 4:99-102
138. Sidorov, G., Rybovskhoz "Ergeninskij" ("Ergeninskij" fish farm). Rybodov.Rybolov., 4:6-7
1973
139. Sim Do Tchek, V riazanskoj oblasti/potomstvo karpa polucheno zavodskim sposobom (In the 1975 Rjazan province. Carp progeny obtained in an artificial way). Rybodov.Rybolov., 3:9-10
140. Sizenev, B., Sovkhoz "Terskiy" ("Terskiy" farm). Rybodov.Rybolov., 9:10-1
1976
141. Skabichevskii, B.O. and V.V. Smolin, Vliianie srokov zalit'ia nagul'nykh prudov na razvitiie estestvennoi bazy (The effect of autumn filling of breeding ponds on the development of food resources). Izv.Gos.Nauchno-Issled.Inst.Ozern.Rechn.Rybn.Khoz., 93:69-74
142. Stangenberg, M., Nowe problemy w ochronie wod przed zanieczyszczeniem. i perspektywy w przyszłości (New problems of water protection against pollution and its future prospects). Chron.Przyr.Oczysta, 30(3-4):5-19
143. Stasiniewicz, K., Wplyw glibokosci wody na wydajnosć naturalna stawow (The effect of water depth on natural productivity of ponds). Gospod.Rybn., 6:8-9
144. _____, Wyniki intensyfikacji produkcji karpia w stawach o roznym pojemnosciach wody (Results of the intensification of carp production in ponds with different water volume). Gospod.Rybn., 3:12-3
145. Studeniskii, S.A., Prodrovye rybovodstvo: itogi i zadach (Pond fish culture: results and aims). Rybn.Khoz., 4:18-23
146. Sukhoverkhov, F.M. and A.P. Sivercov, Prodrovye rybovodstvo (Pond fish culture). Moskow, 1975 Fishchevaia promyshlennost
147. Syrov, V., T. Kozodoeva and Z. Voroshilina, Trekhletnii oborot povyshaet kachestvo produkcii (3-year cycle increases results of production). Rybodov.Rybolov., 2:15
148. Szamborski, J., Niektore elementy ekonomicznej produkcji stawowej (Some elements of economic efficiency of pond production). Gospod.Rybn., 2:3-5
149. _____, O ustaleniu normatyvu efektywnosci ekonomicznej inwestycji stawowych (About the establishment of norms for economic effectiveness of pond investments). Gospod.Rybn., 3:5-6
1968
150. _____, Ogolne wzor krzywej produkcji i krzywej kosztow w gospodarstwach stawowych (General equation of the production curve and cost curve in pond fish farms). Gospod.Rybn., 5:10-3
1969

151. Szczerbowski, J., Produkcja stawu Malik w 14 deultacie (Production of Malik Pond in the 14th biannual cycle). Gospod.Rybn., 16:8-10
152. Szumiec, J., Intensywny chow karpia konsumpcyjnego (Intensive culture of table carp). 1974 Gospod.Rybn., 6:3-6
153. Tarasov, E., J. Koltypin and A. Ivanov, K resheniu problem utylizacii otkhodov zhivotnovodcheskikh kompleksov (The problem of utilizing wastes from complex animal production). Rybovod.Rybolov., 5:11
154. Triamkin, F., Primenenie polimernykh trub (The use of polymeric pipes). Rybovod.Rybolov., 1975 4:11
155. Trifinov, V., Zimovalnye komplekxy (Wintering complexes). Rybovod.Rybolov., 1:11-2 1976
156. Vacek, J., Využití některých statistických metod pro zapřesnění klasifikačních kritérií v rybníkářství (Utilization of statistical methods for improvement of classification criteria in pond fish culture). Ceske Budejovice, Statni rybníkářství, oborovy podnik 1969
157. ———, The analysis of the factors affecting economic efficiency of fish production. 1970 Paper presented to the EIFAC Sixth Session. Krakow, Poland, 18-23 May 1970. Rome, FAO, EIFAC 70/SC 1-4
158. ———, The technological and economic effectiveness of feeds in fish meal production. 1973 Zhivocisna Vyroba, Prague, 18(1):73-82
159. ———, Srovnání efektivity využití půdy v rybníkářství a v zemědělské výrobě (Efficiency of land utilization in fish culture and in agriculture). Rybníkářství a životní prostředí, Ceske Budejovice, XXIV:1-12 1974
160. ———, Some remarks on the analysis of the effectiveness of carp production in intensively managed ponds in 1972. Bul.Vyzk.Ustav Ryb.Hydrobiol., Vodnany, 3-4:3-10 1974b
161. ———, Analysis of carp production in intensively managed ponds in the year 1973. 1975 Bul.Vyzk.Ustav Ryb.Hydrobiol.Vodnany, 1:3-10
162. ———, Economic aspects of the production of rainbow trout in cages. Zyvosiana Vyroba, 1975a 20(11):815-26
163. ———, Selected findings from the analysis of the economic effectiveness of carp production in 1974. Bul.Vyzk.Ustav Ryb.Hydrobiol., Vodnany, 2:27-33 1976
163. Vavruska, A., Studies in the effectivity of pond management under different natural and economic conditions. Bul.Vyzk.Ustav Ryb.Hydrobiol., Vodnany, 2:13-22 1971
164. ———, Analysis of the efficiency of mineral fertilizers in fish-pond management. 1972 Bul.Vyzk.Ustav Ryb.Hydrobiol., Vodnany, 8(1):17-23
165. Weatherly, A.H. and B.M.G. Cogger, Fish culture: problems and prospects. Science, Wash., 1977 197(472):427-30
166. Webber, H.H., The design of an aquaculture enterprise. Proc.Gulf Caribb.Fish.Inst., 24: 1971 117-25
167. ———, Aquaculture ecosystems. Ann.N.Y.Acad.Sci., 245:26-38 1975

168. Webber, H.H. and P.F. Riordan, Problems of large scale vertically integrated aquaculture.
1979 In Advances in aquaculture. Papers presented at the FAO Technical Conference on aquaculture, Kyoto, Japan, 26 May - 2 June 1976, edited by T.V.R. Pillay and W.A. Dill. Farnham, Surrey, Fishing News Books Ltd., for FAO, pp. 27-34
169. Wieniawski, J., Technika wychowu karpi (Techniques of carp production). In Hodowla ryb w stawach. Warszawa, PWRiL, pp. 266-304
170. _____, Podstawowe wiadomości o gospodarce wodnej w stawach (Basic knowledge on water management in ponds). In Hodowla ryb w Stawach. Warszawa, PWRiL, pp. 132-224
171. Winberg, G. and V. Lakhnovich, Nawożenie stawów (Pond fertilization). Warszawa, PWRiL 1968
172. Wisniewska, H., Koszty produkcji pstrąga w Zakładzie Rybackim Szczecinek (Costs of trout production in Szczecinek fish farm). Post-graduate training, IFI, Olsztyn (mimeo) 1978
173. Witkowski, E., Rezerваты przyrody (Nature reserves). Aura, 11:10-2 1976
174. Wlodek, J.M., Current trends in the development of breeding and selection of common carp; an attempt at synthesis. Rocz.Nauk.Roln.(Ser.H), 94(3):123-38
175. Wołoszyn, J., Podstawowe przesłanki techniczno-ekonomiczne projektowania małych zbiorników wodnych. In Kryteria lokalizacji i wykorzystania małych zbiorników wodnych (Technical and economic basis for planning small water bodies. Criteria for the localization and utilization of small water bodies). Wrocław, NOT SITWA, International Scientific and Technical Conference, pp. 61-69
176. Worniallo, J., Próba analizy zależności produkcji narybku karpia od czynników jej intensyfikacji (Preliminary investigation into some agents bearing on one-year carp production). Rocz.Nauk.Roln.(Ser.H), 92(4):139-46
177. _____, Wstępne badania niektórych czynników wpływających na produkcję karczow karpia (Preliminary examination of the dependence of carp fry production on agents for its intensification). Rocz.Nauk.Roln.(Ser.H), 92(4):121-38
178. _____, Badanie wpływu niektórych czynników na produkcję karpia towarowego w cyklu 3-letnim (Studies on the effect of some factors upon the production of marketable carp in a 3-year cycle). Rocz.Nauk.Roln.(Ser.H), 95(4):117-26
179. _____, Statystyczne badanie wybranych problemów gospodarki stawowej (Statistical studies on selected problems of fish pond management). Rocz.Nauk.Roln.(Ser.H), 95(4):127-40
180. _____, Próba analizy efektywności inwestycji w hodowlę stawową karpia na tle efektywności inwestycji w produkcji zwierzęcej gospodarstw rolnych (An attempt to analyse the effectiveness of investments in pond fish culture against the background of animal production in agriculture) (mimeo) 1976
181. _____, An effort to evaluate the influence of temperature differentiation in Poland on pond production of carp. Rocz.Nauk.Roln.(Ser.H), 98(3) 1977
182. Wrobel, S., Korzyści ze stawów (Benefits from ponds). Aura, 9:22-3 1973
183. _____, Przemysłowa technologia produkcji ryb i perspektywy jej rozwoju w Polsce (Commercial fish production and the prospects of its development in Poland). Kosmos, (Ser.A), 6:547-56 1975
184. Zapertova, H., Rezervy povysheniya urovnia proizvoditel'nosti truda v prудovom rybovodstve (Possibilities of increasing labour efficiency in pond fish farming). Rybn. Khoz., 12:74-6 1975

185. Anon., Desert oasis put to a new use. Fish Farming Int., 4(4):6
1977
186. _____, Fish needed in monsoon area. Fish Farming Int., 4(4):7
1977a
187. _____, Pond survey in Bangladesh. Fish Farming Int., 5(1):4
1978

B. UNPUBLISHED PAPERS

188. Apostolski, K. and B. Arsovski, Economic and technical appraisal of different types of fish
1974 culture in Yugoslavia. Material of the EIFAC Working Party on Fish Economics
189. Dobrai, L., General data concerning profitability of Hungarian fish farms. Material of the
1975 EIFAC Working Party on Fish Economics
190. Gerhardsen, G.M., Fish culture operations. Material of the EIFAC Working Party on Fish
1975 Economics, Draft GMG/im 13.3.75
191. Labon, A., Economic evaluation of fish farming with particular reference to cost analysis.
1972 EIFAC/Econ/WP/72
192. Leopold, M., Material of the EIFAC Working Party on Fish Economics
1975
193. Polish Case Study No. 1, Economic policy in respect to fish culture. Material of the EIFAC
1974 Working Party on Fish Economics
194. Polish Case Study No. 4, Investments. Some contributions to the problems of economic
1974 evaluation of fish culture. Material of the EIFAC Working Party on Fish Economics
195. Polish Case Study No. 5, Non-measurable factors. Some contributions to the problems of
1974 economic evaluation of fish culture. Material of the EIFAC Working Party on
Fish Economics
196. Polish Case Study No. 6, Economic situation of small pond complexes. Material of the EIFAC
1975 Working Party on Fish Economics
197. Tal, S., Preliminary observations on new methods of fish culture in Israel. Material of
1974 the EIFAC Working Party on Fish Economics
198. Vacek, J., Analysis of the efficiency of carp production in ponds with intensive and less
1974a intensive farming. Material of the EIFAC Working Party on Fish Economics
199. Wrobel, S., Some contributions to the problem of economic evaluation of fish culture (Poland).
1974 Material of the EIFAC Working Party on Fish Economics

EIFAC TECHNICAL PAPERS ISSUED

- EIFAC/T1 Water quality criteria for European freshwater fish. Report on freely divided solids and inland fisheries (1964)*
- EIFAC/T2 Fish diseases. Technical Notes submitted to EIFAC Third Session by Messrs J. Heyt, H. Menn, C.J. Rasmussen and A. van der Struk (1965)*
- EIFAC/T3 Feeding in trout and salmon culture. Papers submitted to a Symposium. EIFAC Fourth Session (1967)**
- EIFAC/T4 Water quality criteria for European freshwater fish. Report on extreme pH values and inland fisheries (1968)*
- EIFAC/T5 (Rev. 1) Organization of inland fisheries administration in Europe. Revised edition (1974)*
- EIFAC/T6 Water quality criteria for European freshwater fish. Report on water temperature and inland fisheries based mainly on Slavonic literature (1966)**
- EIFAC/T7 Economic evaluation of inland sport fishing by Ingemar Norling (1968)**
- EIFAC/T8 Water quality criteria for European freshwater fish. List of literature on the effect of water temperature on fish (1969)**
- EIFAC/T9 New developments in carp and trout nutrition. Papers submitted to a Symposium. EIFAC Fifth Session (1969)**
- EIFAC/T10 Comprehensive study of laws and regulations governing the international traffic in live fish and fish eggs by F.B. Zenny. FAO Legislative Branch (1969)**
- EIFAC/T11 Water quality criteria for European freshwater fish. Report on ammonia and inland fisheries (1970)*
- EIFAC/T12 Salmon and trout feeds and feeding (1971)*
- EIFAC/T13 Some considerations on the theory of age determination of fish from their scales - Finding proofs of reliability by R. Sych (1971)*
- EIFAC/T14 EIFAC consultation on eel fishing gear and techniques (1971)**
- EIFAC/T15 Water quality criteria for European freshwater fish. Report on monohydric phenols and inland fisheries (1972)*
- EIFAC/T16 Symposium on the nature and extent of water pollution problems affecting inland fisheries in Europe. Synthesis of national reports (1972)**
- EIFAC/T17 Symposium on the major communicable fish diseases in Europe and their control. Report (1972)*
- EIFAC/T17 Suppl. 1 The major communicable fish diseases of Europe and North America. A review of national and international measures for their control by P.E. Thompson, W.A. Dill and G. Moore (1973)*
- EIFAC/T17 Suppl. 2 Symposium on the major communicable fish diseases in Europe and their control. Panel reviews and relevant papers (1973)**
- EIFAC/T18 The role of administrative action as a tool in water pollution control by G.K. Moore (1973)*
- EIFAC/T19 Water quality criteria for European freshwater fish. Report on dissolved oxygen and inland fisheries (1973)*
- EIFAC/T20 Water quality criteria for European freshwater fish. Report on chlorine and freshwater fish (1973)*
- EIFAC/T21 Water quality criteria for European freshwater fish. Report on zinc and freshwater fish (1973)*
- EIFAC/T22 Ecological diagnosis in salmonid streams - Method and Example by R. Guinet et al. (1975)*
- EIFAC/T23 Report on the Symposium on methodology for the survey, monitoring and appraisal of fishery resources in lakes and large rivers (1974)*
- EIFAC/T23 Suppl. 1 Symposium on the methodology for the survey, monitoring and appraisal of fishery resources in lakes and large rivers - Panel reviews and relevant papers. Vol. I and II (1975)**
- EIFAC/T24 Report on fish toxicity testing procedures (1975)*
- EIFAC/T25 Workshop on controlled reproduction of cultivated fishes - Report and relevant papers (1975)**
- EIFAC/T26 Economic evaluation of sport and commercial fisheries. Report and technical papers of the Second European Consultation held in Göteborg, Sweden 22-24 September 1975 (1977)**
- EIFAC/T27 Water quality criteria for European freshwater fish. Report on copper and freshwater fish (1976)*
- EIFAC/T28 Joint ICES/EIFAC Symposium on eel research and management (Anguilla spp.) Report (1976)**
- EIFAC/T29 Water quality criteria for European freshwater fish. Report on the effect of zinc and copper pollution on the salmonid fisheries in a river and lake system in central Norway (1977)*
- EIFAC/T30 Water quality criteria for European freshwater fish. Report on cadmium and freshwater fish (1977)*
- EIFAC/T31 Report on the Symposium on Finnish Nutrition and Feed Technology (1976)*
- EIFAC/T32 The value and limitations of various approaches to the monitoring of water quality for freshwater fish (1978)*
- EIFAC/T33 Guidelines for sampling fish in freshwater (1980)*
- EIFAC/T34 EIFAC fishing gear intercalibration experiments (1979)*
- EIFAC/T35 Report of the EIFAC workshop on mass rearing of fry and fingerlings of freshwater fishes (1979)*
- EIFAC/T35 Suppl. 1 EIFAC Workshop on mass rearing of fry and fingerlings of freshwater fishes/Papers (1979)*
- EIFAC/T36 Report of the EIFAC/UNESCO and ICES working group on standardization of methodology in fish nutrition research (1980)*
- EIFAC/T37 Report on combined effects on freshwater fish and other aquatic life of mixtures of toxicants in water (1980)*
- EIFAC/T38 Report of the technical consultation on the allocation of fishery resources (in press)*
- EIFAC/T39 Utilization of heated effluents and recirculation systems for intensive aquaculture (1981)*
- EIFAC/T40 Problems of fish culture economics with special reference to carp culture in eastern Europe, by M. Leopold (1981)*
- EIFAC/T41 Report of the EIFAC Workshop on fish-farm effluents, by John S. Alabaster (1982)*

* In English and French

** Bilingual English and French

